Social Fitme: A Fully Personalized Virtual Try-on System Using Embodied Avatars

LIU YUHAN
44191051-9

Master of Engineering

Supervisor: Prof. Jiro Tanaka
Graduate School of Information, Production and Systems
Waseda University

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Abstract

Social interaction in the shopping context can improve consumer's shopping experience, giving them opportunities to exchange fashion ideas, share outfits, and build relationships with each other. However, consumers do not always have the chance for social interactions when shopping online. Augmented Reality (AR) technology can enable social interactions among users, and allow them to interact with virtual content while engaging in natural communication in the real world.

In this paper, we propose a holographic AR-based 3D try-on system, Social Fitme, that enables multiple users a novel and intuitive sharing experience where they can view garments fitted onto their own personalized virtual body and share their dynamic virtual try-on experience with others. Users can try clothes on their friends directly, communicate with each other thereby making a more confident decision when shopping online. We conducted a user study to compare our proposed system with an independent AR-based try-on system. Our findings indicated that Social Fitme can greatly improve the shopping pleasure of users and provide a more engaging and effective shopping experience for users. Interactions between users can help them explore a completely new style, enhance their relationships, and strengthen their social connections.

Keywords: augmented reality, virtual try-on, virtual avatar

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Contents

List of figures

List of tables

Chapter 1

Introduction

1.1 Introduction

E-commerce is one of the fastest-growing fields in the world. Nowadays, more and more customers around the world are buying clothing, shoes, and accessories online. While almost 56% of consumers still reported apprehension about physical garment style and fit as major sources of concern with online shopping. The mismatched exception between real products and online pictures become the biggest obstacle to online shopping. Especially for fashion fields, the perceived difference between the actual product and body size makes it difficult for consumers to determine whether it suitable or not, which may negatively affect their shopping experience and purchase intentions. Furthermore, when shopping online, it is very difficult for consumers to share their decisions with friends, and quickly get feedback from others. On the other hand, consumers can try on clothes in person, listen to verbal recommendations from relatives, relatives, and friends, and then make a purchase decision that suits them.

To address the above problem, we propose a 3D virtual try-on system using personalized models (Figure 1.1). Social Fitme, which allows multiple users to virtually fit garments together. Our system reduces the gap between offline shopping and online shopping and enhances the social experience of online shopping, which allows users to experience the pleasure of physical shopping with friends, choose clothes for each other and get quick feedback in real-time. The aim of the system is to improve the user experience of online shopping by enabling social interaction with each other while engaging with a more personalized virtual try-on system. Users can virtually try-on clothes using mobile and view the personalized virtual avatar doing augmented motions in the real world. They can talk to each other and give some fashion comments in real-time when using the system.

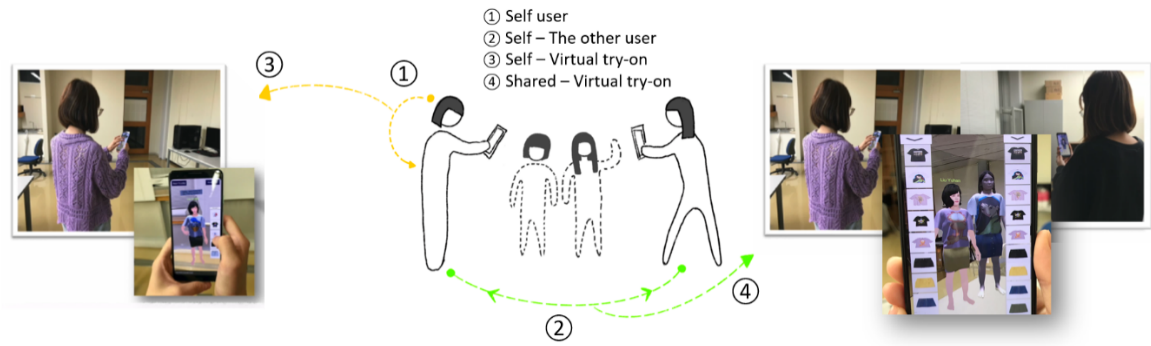


Fig. 1.1 Social Fitme, an AR-based try-on system for multiple users to share their fitting experience together.

Other than traditional online shopping with image-only, our research is to make a fully personalized virtual try-on system which can provide users a more realistic and interactive virtual try-on experience. The main contributions of this research can be summarized as follows:

(1) A fully personalized virtual try-on system that enables users to view the virtual garment interactively and immersively in 360 degrees, and enabling users to check their garment on a personalized virtual body augmented with human-like motion in the real-world. Users can try clothes on their friends directly and quickly view the effect of their dressed body. **(2) A socially interactive virtual try-on system** that supports an intuitive sharing experience for users. Users can experience social interactions during their virtual try-on process, such as sharing their dynamic dressed virtual body with each other. Social Fitme strengthen the social connections between users when shopping online, interactions between users can help them make a more confident decision and explore a completely new style.

To understand the user's acceptability, we conducted a user study to evaluate the effectiveness of our Virtual try-on system.

1.2 Organization of the thesis

The rest of the thesis is organized as follows: Chapter 2 introduces the background of the thesis, we talk about the development of online shopping and the future of online shopping. we also introduce virtual try-on technology and show how we figured out our standards and requirements. In Chapter 3, a brief review of previous research on the personalized virtual avatar, different virtual try-on levels, and the role of an embodied avatar in social augmentation is presented. Chapter 4 is about the research goal and also the approaches. Chapter 5 is the system design part, we describe the system structure and overview, including the penalization of embodied avatar and sharing the virtual try-on experience of other users. Chapter 6 will be the system implementation part where the detailed environment and implementation will be shown in this chapter. Chapter 7 is concerning the evaluation, we present our evaluation result according to our preliminary evaluation. The last part, Chapter 8, will be the conclusion and future work part, where we will conclude the previous content of our thesis with a brief summary and discuss the future work.

Chapter 2

Background

2.1 The Development of Online Shopping

E-commerce is one of the fastest-growing areas in the world. As of the end of 2017, the e-commerce niche has grown by 21%, which is impressive, reaching US$2.3 trillion. 68% of online customers worldwide purchase clothing, shoes, and accessories abroad[1]. Nowadays, in addition to websites dedicated to fashion e-commerce, shopping portals such as eBay and Amazon have dedicated their entire extension to a wide range of fashion fields[2].

In recent years, due to the convenience provided by online shopping, it has become more and more popular all over the world. For consumers, online shopping gives them the opportunity to buy goods in the comfort of their homes. In addition, consumers can compare prices in different online shops to get the best value for money[3]. For retailers, online shopping enables them to cut overhead costs without paying expensive rent. Although the number of consumers purchasing clothes online is increasing, almost 56% of consumers still reported apprehension about physical garment style and fit as major sources of concern with online shopping. The difference between real products and online pictures will become the biggest obstacle to online shopping. Especially for fashion fields, the perceived difference between the actual product and body size makes it difficult for consumers to determine fit, which may negatively affect their shopping experience and purchase intentions.

In the future, online shopping will focus on solving the above problems. I think about what possibilities future can bring and offer to online shopping

- Widened reality – online fitting-rooms.

  The difference between online shopping and physical fitting is "the lack of direct try-on experience". When customers shop in a physical store, they usually trying clothes on to assess if garments are suitable or not before purchasing. However, when shopping online, consumers have the problem of not being able to try them on. they might worry about how well the clothes will fit on their own body. Therefore, virtual try-on technology appears. In the future, the online fitting room will be can provide users with a virtual try-on experience, which may increase the user's shopping experiences and increase their purchase intention.

- Artificial intelligence and personalization of shopping.

  Another problem with online shopping is that it is difficult for consumers to evaluate fit, consumers cannot measure the effect of clothes on their bodies like physical fitting. The absence of "true fit" may disappoint customers when shopping online. Hence, the personalization which can reflect the user's body shape and facial appearance could be an important factor that can make the user's experience more accurate, engaging, and increasing the consumer's confidence when making purchasing decisions on garments online.

2.2 Virtual Try-on Technology

Despite the increasing popularity of online shopping, physical stores still retain their main advantage-customers can try them before buying products. However, as online shopping becomes more and more popular, brands are also striving to provide an overall user experience on their digital channels[4]. The advancing virtual try-on (VTO) technology makes it possible to try on garments in just a few seconds. Moreover, virtual try-on combined with Augmented reality (AR) or Virtual reality (VR) technologies can give consumers a more realistic try-on experience. Consumers can get a better sense of what they look like when wearing the products. Several fashion firms utilized AR technology in the form of the mobile application, including Uniqlo and Gap [5]. Using VR technology, consumers can feel like they are physically in a virtual fitting room. Several fashion retailers have provided this kind of shopping experience, such as Alibaba and Dior[5].

Earlier work on virtual try-on is mostly conducted in computer graphics [11], [12], [14]. Previous work focused on two types of virtual try-on: 2D overlay virtual try-on, 3D virtual try-on.

- 2D overlay virtual try-on: 2D VTO system overlays a projected 2D image of products onto an image of the user and the real environment around the user, also called a magic mirror. Figure 2.1 shows an example of a 2D overlay virtual try-on.

Fig. 2.1 2D overlay Virtual Try-on

- 3D virtual try-on: unlike the 2D images, 3D garment models perform precise garment simulation rather than just a 2D overlay. In addition, the 3D virtual try-on system provides virtual fitting experiences on a default virtual avatar. In 3D virtual try-on, 3D garment model matching to 3D avatars presents a more accurate representation of the garment and its fit. It also provides users a multi-angle view of the garments. Figure 2.2 shows an example of a 3D virtual try-on.

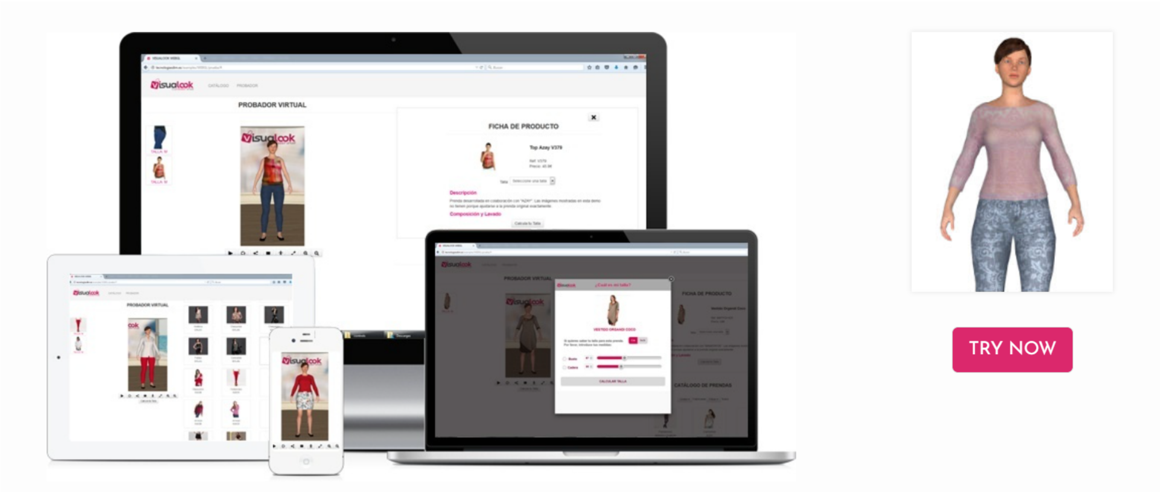


Fig. 2.2 3D Virtual Try-on

In conclusion, virtual try-on technology can provide a lot of benefits for consumers. The consumers can have the opportunity to try the desired products and make their purchasing decisions easier when shopping online and hence makes the overall user experience better and more personalized.Besides being a useful tool for customers' shopping experience, a virtual try-on can be a valuable tool for sale. For brands, a virtual try-on can make a significant difference when it comes to marketing and sales. Virtual try-on allows customers to try on dozens of products instantly, and even get related product recommendations, encouraging upsales[4].

Chapter 3

Related Work

3.1 Personalized Virtual Avatar

The main problem with online shopping is the lack of direct try-on experience, which may lead to an increase in perceived risk of purchases due to the difficulty in judging the product fit [6]. Some literature provides virtual fitting experiences on a default virtual avatar rather than one generated based on the user's own body [7, 8]. The absence of "how they fit" may influence customer purchase intention when shopping online and decrease consumer enjoyment in the shopping process.

Compared to standardized avatars, customizing a virtual avatar with their own features may provide users a sense of virtual self. The creation of realistic self-avatars is important for VR- or AR-based VTO applications that aim for improving the acceptance of personalized avatars, thus providing users a more realistic and accurate try-on experience. Recent studies focused on investigating the personalized VTO experience with a customized virtual avatar created using the user's own face and body figures. Personalized VTO provides a more realistic user experience when users try clothes on their virtual self [9]. Yuan et al. customized a partially visible avatar based on the user's body size and skin color and used it for proper clothes fitting. They found that using a personalized avatar can increase customer purchase choice confidence [10]. Nadia Magnenat-Thalmann et al. proposed a VTO system that allows users to virtually fit physically-simulated garments on their generic body model [11]. Yang and Xiong found that a VTO experience with a personalized avatar significantly increases customer satisfaction and decreases the rate of product return [12]. Moreover, female as the main target customers of online shopping, they usually have high body esteem of their virtual body. Anne Thaler et al. investigated gender differences in the use of visual cues (shape, texture) of a self-avatar for estimating body weight and evaluating avatar appearance. In terms of the ideal body weight, females but not males desired a thinner body [13].

3.2 Virtual Try-on Levels of Personalization

Depending on the avatar's level of personalization, the avatar representing the user may or may not provide a real sense of self [14]. According to the avatar's similarity to the user, virtual try-on systems can be divided into four levels as proposed Merle et al. [9]:

(1) Mix-and-match: Same as traditional online shopping where users can select the products using only online images.

(2) Non-personalized VTO: Some virtual try-on experiences based on a default virtual avatar rather than one generated from the user's own body [15–17]. The lack of precision in describing users and products reduces users' virtual try-on experience.

(3) Personalized VTO: Virtual avatar models are customized with personal features (face color, height, weight, bust size, and body shape).

(4) Highly personalized VTO: Virtual avatar models are customized with personal features including the face model.

The highly personalized VTO requires more personalized information, which leads to better information recall for users. Users can gain a better understanding of wearing clothes on their own body, increasing their purchase choice confidence [18–21].

3.3 Embodied Avatar in Social Augmentation

B.Back et al demonstrated the synchronous interpersonal visuo-tactile stimulation led to the participants perceiving the other face to be similar to their own[22].M. Gonzalez et al.

investigated the level of avatar enfacement, they found that using facial animation can increase the enfacement illusion and avatar self-identification in social virtual environment[23]. Moreover, Slater et al. noted that a completed virtual body representation can enhance the sense of presence in a virtual environment[24].

Surveys on virtual avatars have shown that embodied avatar can increase the self-identification and self-body ownership in VR environment. However, the emotional elements will influence the user experience under the virtual fitting environment? S. Noordin et al. presented an Augmented reality and motion capture (ARMC) model to verify the needs for profound emotional elements, the result showed that the emotional value and social value had an indirect effect on online shoppers' usage intention[25].

As a summary of previous research, we found that so far there is a lack of research exploring the dynamic VTO experience with personalized motions and facial expression. What's more, the social features as an important expression of human behavior that has been ignored in the previous virtual try-on system.

Therefore, we propose a fully personalized motion VTO system. We customized the virtual avatar based on the user's own face and body figures. We personalized the user's actual posture or movement as virtual avatar animation. Moreover, we personalized the user's facial motion as the facial expression of a virtual avatar.

Comparing with the existing system, our proposed fully personalized virtual try-on system tries to make the improvement from these two parts:

(1) **Personalization:** Existing VTO systems only personalized user's presence of the real body (body shape and face image). Our proposed AR-based virtual try-on system improves the level of personalized avatars. We provide a new way for users to view the virtual garment by the augmented personalized motion and facial expression, which may increase the user's perception of their virtual avatar when trying the virtual garments on.

(2) **Social Interactivity:** Most existing VTO systems only overlay the 2D images of the garment onto the user's real body, without using 3D information and not allowing users to check the garment from different viewpoints. Our proposed AR-based virtual try-on system enables multiple users to view a life-size personalized avatar with garment models

and posing or walking augmented in the real-world. Users can view the virtual garment interactively and immersive in 360 degrees. Furthermore, in order to simulate a more realistic fitting environment for users, we adding the "social features" for users, which may enrich the interactivity of the virtual try-on system.

Chapter 4

Research Goal and Approach

4.1 Goal

The goal of this research can be summarized below:

- **Improve the Personalized Virtual Try-on System**

  The current virtual try-on system only adopted the personalized virtual avatar based on the user's appearance. We think virtual try-on with personalized human motion and facial expression can provide a more engaging shopping experience for users and thus increase user's purchase intention. Therefore, we propose **a fully personalized VTO System** which can allow users to try-on clothes on the Embodied Avatars with facial expression, motion.

- **Simulate a more realistic physical fitting**

  So far there is a lack of research exploring the dynamic VTO experience with social features. Besides, in real daily life, we often buying clothes with our family members and friends. To provide users a more realistic physical fitting environment, we add the social factors to our virtual try-on system, which offers users **a social sharing interactive virtual try-on experience**.

4.2 Use Case

With the development of e-commerce, more and more consumers tend to buy clothes online. While consumers still have difficulties imagining what they might look like. In addition, compared to the physical fitting, online shopping is a lack of direct try-on experience. While, in our daily life, we usually go shopping with our friend or family, which can add to the fun of shopping.

we propose a holographic 3D virtual try-on system that enables consumers a novel experience where they can view garments fitted on their own personalized virtual body and share their virtual try-on experience with others to get some fashion comments from other people(Figure 4.1).

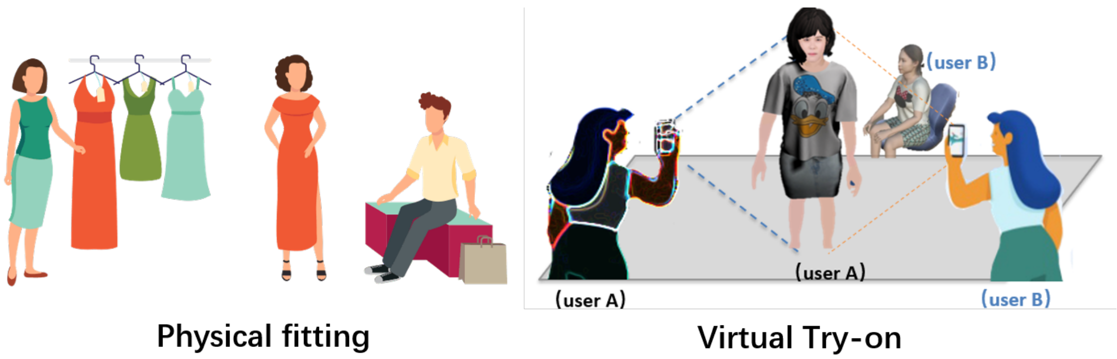


Fig. 4.1 Physical Fitting Vs. Virtual Try-on

4.3 Approach

A big challenge for the user when shopping online is the lack of a direct try-on experience. This research concentrated on using Augmented Reality to simulate the virtual try-on experience for users. To achieve the two goals of our research, we design the structure of a virtual try-on system as Figure 4.2 shows. The design principles are as follows:

(1) Build **a fully personalized VTO System using embodied avatar**

We first generate a personalized avatar for users. To build the embodied avatar for users, we personalize the user's facial expression using a Kinect depth sensor to capture the motion and facial expression of users.

(2) Provide users **a sharing interactive Virtual try-on experience with other people**

To increase the user's intention of usage, we deployed our virtual try-on system to Android smartphone, which is more convenient for users using. To enrich the interactivity of the system and increase the connection between users, we add social features to our system. So that users can share their try-on experience with other people and visualize the garments from arbitrary viewpoints at the same time.

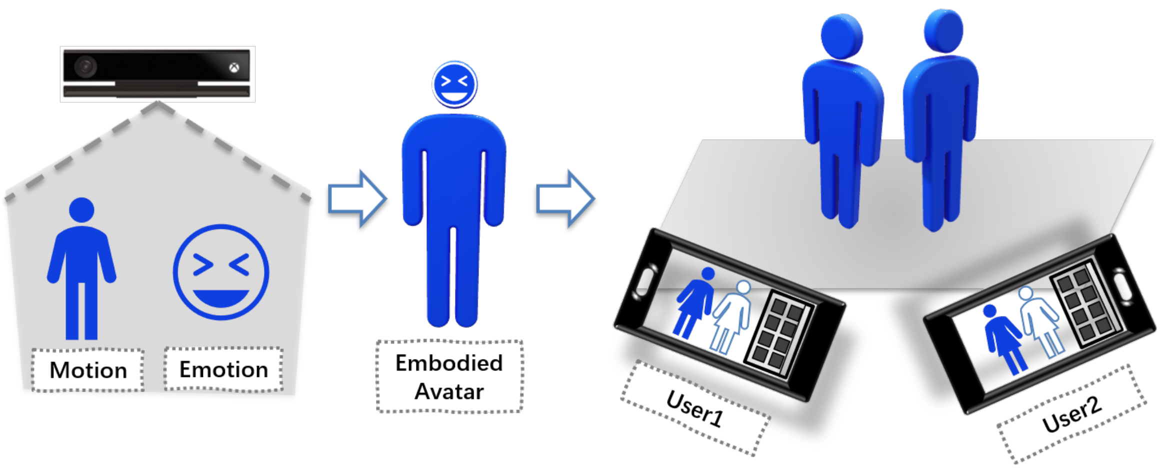


Fig. 4.2 System Structure

Chapter 5

System Design

In this chapter, we will introduce our system design and each important piece of our approach. To demonstrate the effectiveness of a fully personalized virtual try-on experience, we equipped the sharing 3D virtual try-on system with two key points:

1. **A fully personalized VTO System with embodied avatars**: Personalize the appearance, facial expression, and motion for users.
2. **Social Fitme, a sharing interactive VTO experience**: Sharing VTO experience with co-located users.

5.1 System Overview

Figure 5.1 shows the overall structure of our system. Our fully personalized virtual try-on system is composed of embodied avatar personalization, sharing virtual try-on experience.

1. **Embodied avatar personalization:** we personalize the user's virtual avatar using their face image and body image. A 2D face image is used for generating the face model of the user, while a 2D full image is used for generating the body model of the user. we then integrate the body and face model into their personalized virtual avatar. To generate the embodied avatar for users, we need to capture the user's motion and facial expression using the Kinect depth sensor. After that, we can attach the facial

animation and motion animation to the generated personalized avatar as the embodied avatar of the user.

2. **Sharing virtual try-on experience:** we adopt the AR(Augmented Reality) to simulate the virtual try-on experience for users. The users can view their embodied virtual avatar doing daily life activity in the real environment and share their virtual try-on experience with other people.

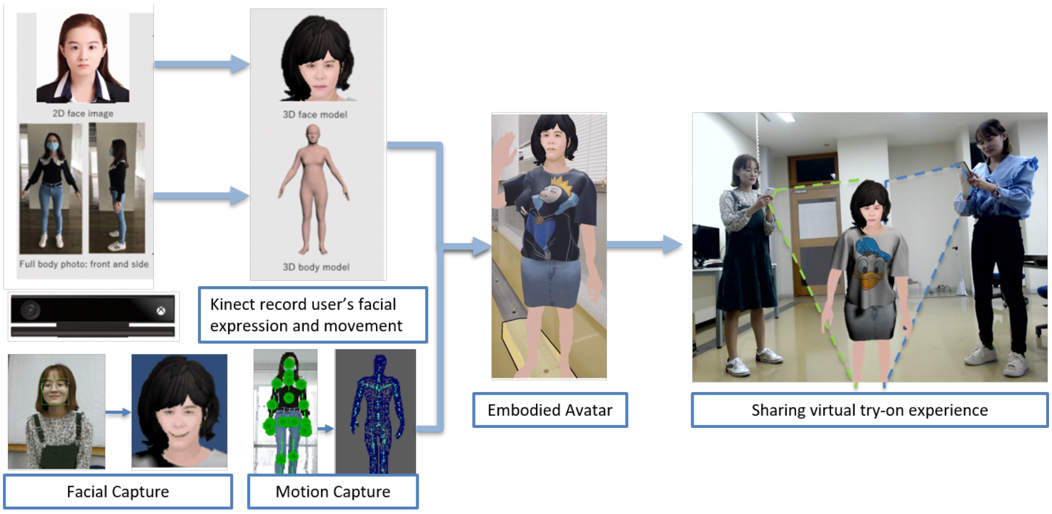


Fig. 5.1 System Overview

5.2 System Structure

As we have mentioned above, our research contains two-part. The first parts are directly related to the avatar: how to personalize an embodied avatar. The second part concerning about the sharing experience, how to share the virtual objects with multiple users.

- Part 1 is about embodied avatar penalization. We explain how we personalize the motion and facial expressions of users and how we optimize the avatar.
- Part 2 is about the sharing part. We share the virtual objects with multiple users using the AR cloud. And we explain the way of sharing and synchronizing the information of animation, position, and voice.

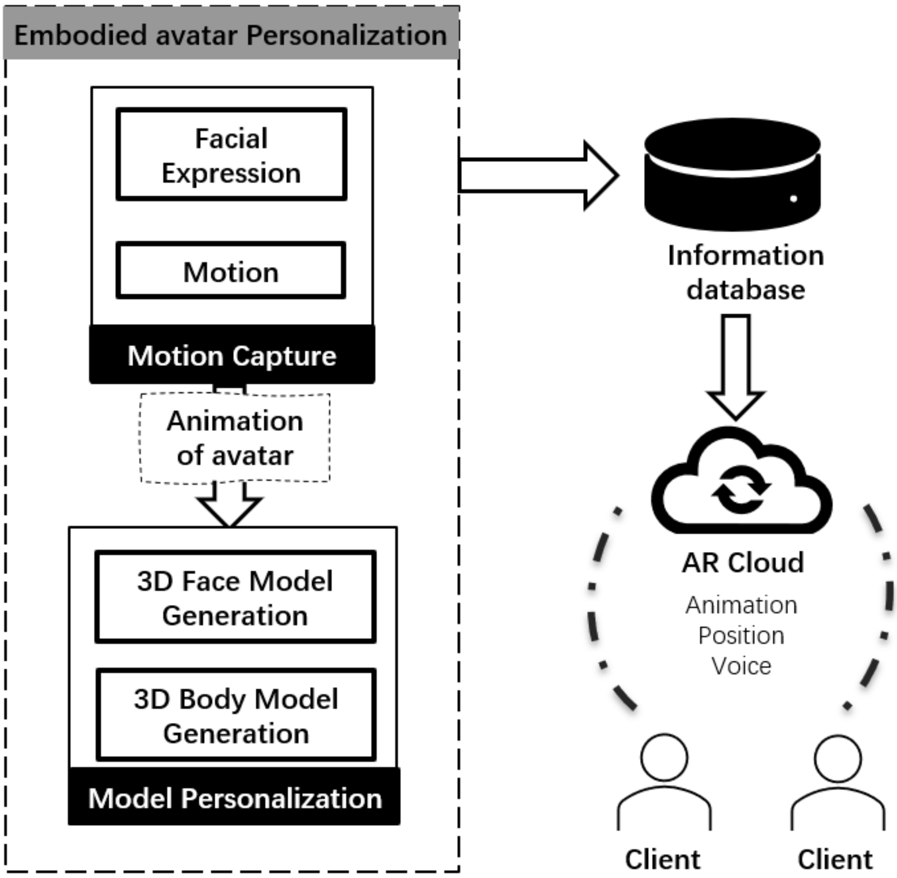


Fig. 5.2 System Structure

Figure 5.2 shows the structure of the proposed system: Soical Fitme, a fully personalized virtual try-on system.

- **Embodied Avatar Penalization**: we using motion capture technology to record the user's motion and facial expression, and convert the motion capture data to animation and attach the animation to the personalized human model. The personalized avatar is generated based on the user's facial and body features. we generate the 3D face model and 3D body model of the user, and store the information including the virtual avatar with its animation in the information database.

- **Sharing VTO experience**: we implement the sharing virtual try-on system using the embodied avatar. The embodied avatar with its information will be uploaded to the AR cloud and share with multiple clients to assess at the same time,

5.3 Fully personalized Virtual Try-on using Embodied Avatars

Depending on the avatar's level of personalization, the avatar representing the user may or may not provide a real sense of self. According to the avatar's similarity to the user, virtual try-on conditions can be shown as following figure 5.3. According to the personalized information of users exposed in the virtual try-on system, the VTO condition can be simplified to the two conditions:

1. Non-personalized virtual try-on system use no personal information of users, which allows users to simulate try-on experience on a default avatar represented to themselves.

2. Personalized virtual try-on system uses less personal information of users, which allows users to simulate try-on experience on a personalized avatar generated based on the user's appearance.

In our research, we propose a fully personalized VTO system using more personal information of users, which allows users to simulate a try-on experience on an embodied avatar. We customized the virtual avatar based on the user's own face and body figures. In addition, We also personalized the user's actual motion and facial expression for the user.

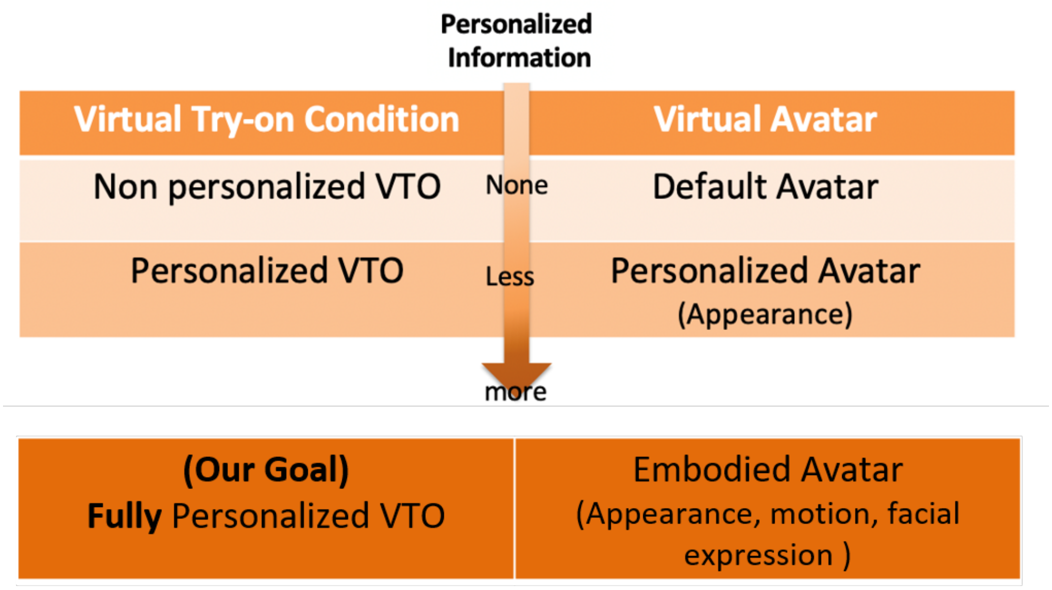


Fig. 5.3 Design Approach

5.3.1 Personalize Embodied Avatar

Embodied Avatars is a kind of virtual avatar that can interact with humans using some verbal and nonverbal language like humans do (such as gestures, facial expressions, and so forth). An avatar represents a user in a distributed virtual environment has been a research issue in social communication. It has been proved that embodied avatars have greater expressive capabilities and naturally embodied avatars have been used to explore the role of social signals[26]and emotions[27]in human-computer interaction. while little serious research attention in the embodiment is the embodied avatars in a virtual fitting environment.

Hence, to investigate whether the embodied avatar can enhance the user's shopping experience and provide the user a more engaging virtual try-on experience, we proposed a fully personalized virtual try-on system using embodied avatars(Figure 5.4). In our virtual try-on system, the emotional expression and motion of embodied avatars will be personalized using motion capture technology. To make sure the motion of the embodied avatar, the skinning and skeleton rigging should be done in advance.

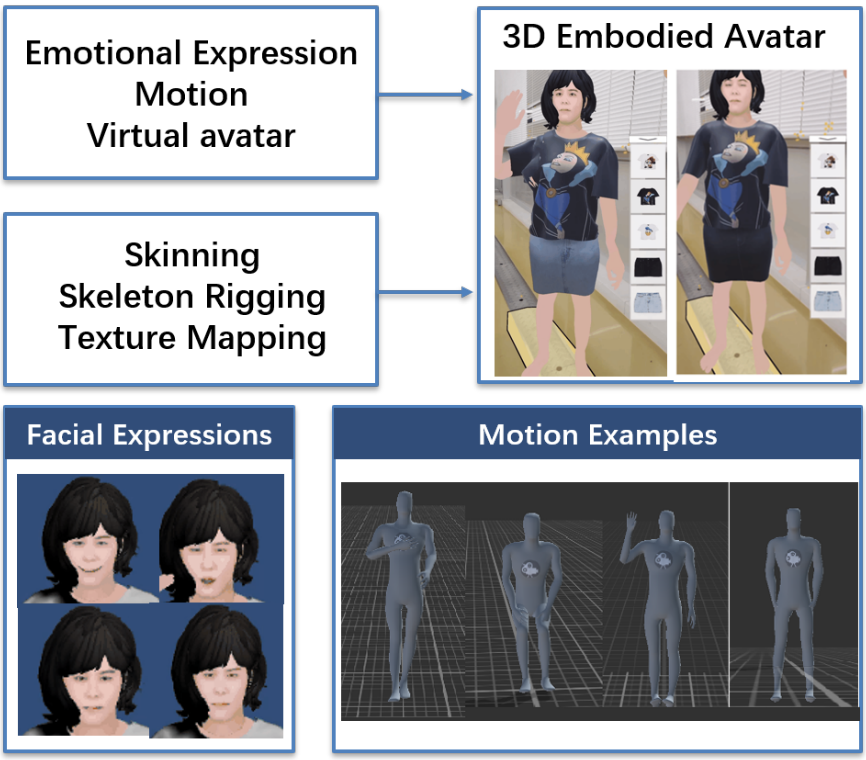


Fig. 5.4 Embodied Avatar

Due to the lack of "physical fitting" in the online shopping experience, consumers may have a gap between actual and perceived body size, which may make them difficult to examine "true fit" on their own body and influence their purchase selection while shopping online[28].

Therefore, the virtual human body should have an appropriate 3D representation corresponding to the real user's body, face features, and body movement. Daily life motions such as walking and sitting may potentially provide users a lifelike shopping experience. Facial expression can show the users' emotional attitude to products in real-time.

To allow users to get a feeling of how the garment matches their actual body, we first personalized users' own embodied avatar based on the user's human body shape and face features.

The personalization of embodied avatars can be divided into three steps:

1. Personalize the appearance of avatar

Figure 5.5 shows the overview of personalizing the virtual avatar. We generate a 3D face model using a 3D avatar SDK and generated a 3D body shape of the user from the two front and side photo of the user using 3DLook software. And then we integrate the 3D face model and 3D body model into one human model.

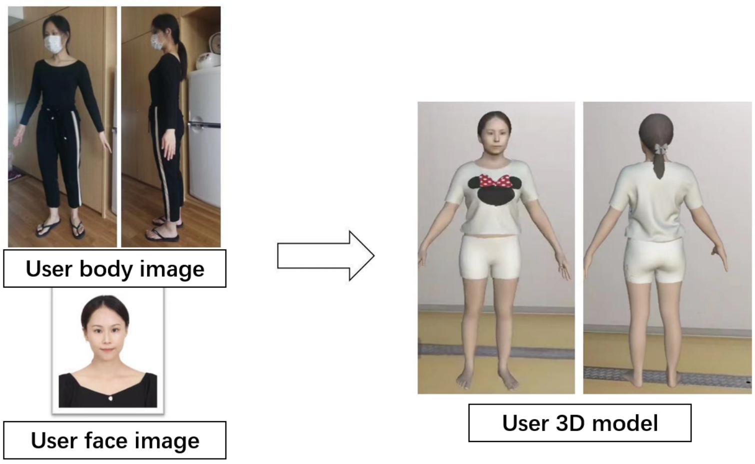


Fig. 5.5 Personalize virtual avatar

- **Face Model Generation**: personalized the appearance for users. 3D Avatars SDK combines complex computer vision, deep learning, and computer graphics techniques to turn 2D photos into a realistic virtual avatar. we use a front of the face image of the user as input, the output can be a fixed topology of a head that included user hair and neck using 3D Avatar SDK(Figure 5.6).

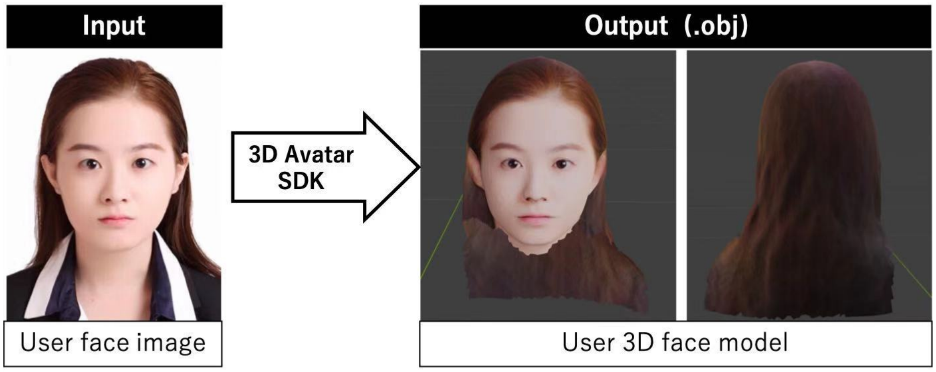


Fig. 5.6 Face model generation

- **Body Model Generation**: personalized the human body shape for users. We collect the basic information of the user: height and weight. To obtain the 3D body model of the user, we gather the two full front and side images of the user as the input of 3DLook software and generated a 3D model based on the basic information and body photos of the user. The output is .obj 3D file format, which can allow us to integrate the face model and body model together in Blender(Figure 5.7).

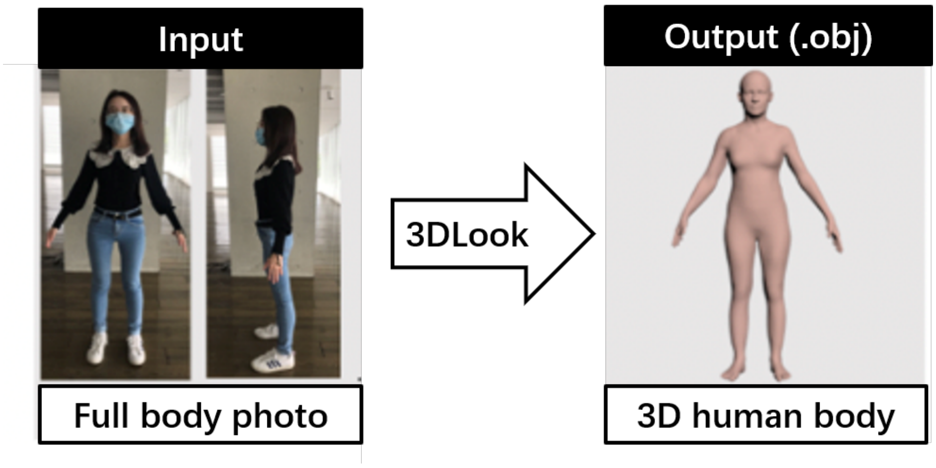


Fig. 5.7 Human model generation

2. Personalize the facial expression of avatar

As an important element of embodied avatars, facial expression, can provide a more interactive shopping experience. As a facial expression of the virtual avatar can enhance user's identification when they are in a social virtual environment. Moreover, personalized facial expressions can show the user's own emotional attitude towards products. Therefore, we think the recorded facial expression may increase the user's perception of their virtual avatar.

We personalized the facial animation of the virtual avatar with the user's facial expression. The workflow of personalizing the avatar's facial expression is shown in Figure 5.8, which consists of three sections: motion capture, personalized facial expression, and facial animation library.

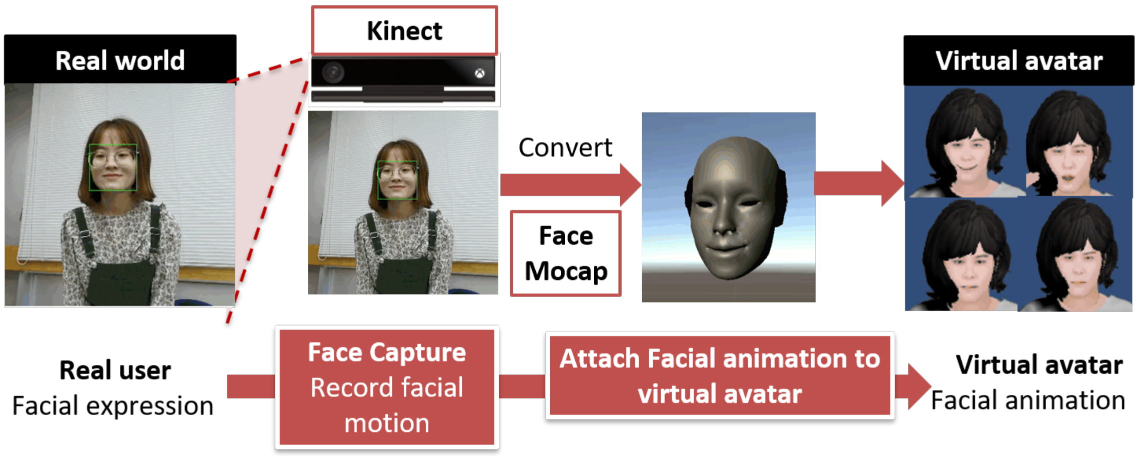


Fig. 5.8 Workflow of recording facial expression

- **Motion Capture**: using Kinect depth sensor to track user's facial expression.

  We use a Kinect depth sensor to capture user's facial expressions in the real world. Then convert the facial motion capture data into facial animation by Cinema Face Mocap.

- **Personalized Facial Expression**: attach user's facial expression to virtual avatar track.

  The face model of the virtual avatar should have the entire eyeball and teeth in. we blender shape the face model to make sure that facial muscle can be controlled by calculated numbers. Then we can attach the captured facial motion to the generated virtual avatar.

- **Facial Animation Library**: prepare several facial expression for the user.

  we capture several facial motions of users and build a facial animation library to express user's emotions (smile, sad, talking).

3. Personalize the motion of avatar

To allow users to gain a sense of the real fit of the clothing on themselves, we personalized their virtual avatar. However, when users try on clothes in an offline shop, they may perform certain activities (e.g., sitting, walking, posing, etc.) to check whether the clothes are suitable.

Previous research provided virtual try-on with motions. Gültepe et al. provided a realistic fitting experience with customized static poses using a depth sensor [29]. Adikari et al. introduced a virtual dressing room for real-time simulation of 3D clothes with users performing various poses [30]. These methods do not allow users to view clothes that match their body from arbitrary angles. So far, there is a lack of research exploring the dynamic VTO experience with personalized motions.

We personalized the animation of the virtual avatar with the user's movements, which allows users to gain a sense of wearing clothes on their own body with their own poses. The workflow of personalizing the avatar motion is shown in Figure 5.9, which consists of three sections: motion capture, personalized movement, and animation library. To gather users' individual movements, we use the Kinect V2 depth sensor to record postures and user movements and create their own animation library for our system. The recorded animations are then smoothed out using Maya and are then attached to the user's virtual avatar.

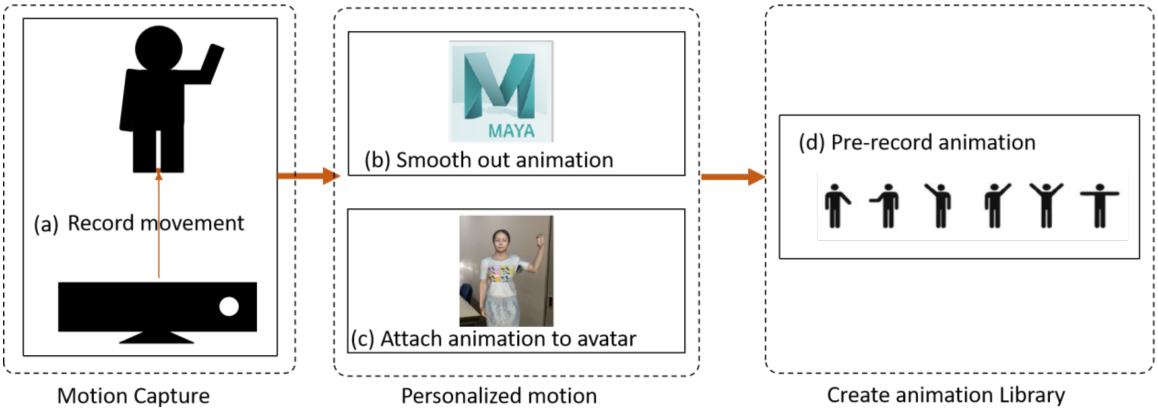


Fig. 5.9 Work flow of recording personalized user motion

We created an animation library including various pre-recorded animations captured by the Kinect V2 depth sensor. We recorded users' movements and postures in daily life, such as walking, sitting, waving, and shaking hands. Figure 5.10 gives some examples of motion animation.

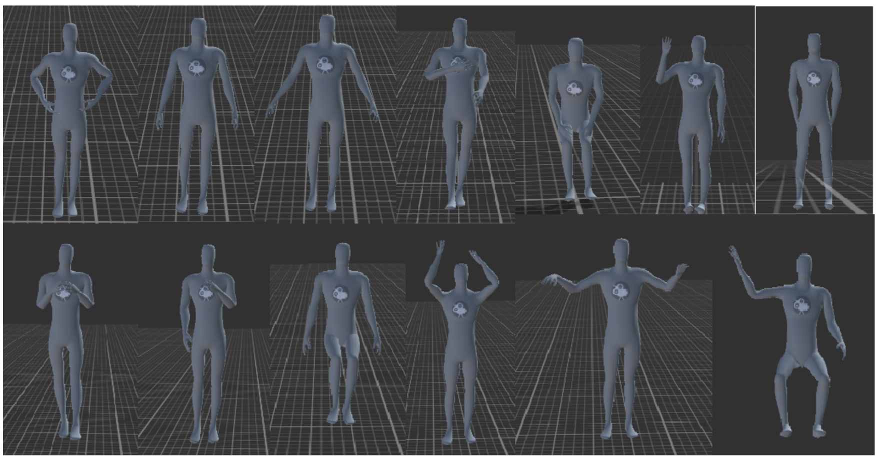


Fig. 5.10 Motion animation library

5.4 AR-based Virtual Try-on Experience

Both AR and VR can provide users with an enriched and immersive experience during virtual try-on. Specifically, when compared to traditional online shopping websites, VR and AR are perceived as more useful for users since they can provide a fuller visualization of the look and feel of the product. Our previous work found that AR- and VR-based try-on technologies are better than traditional online shopping and provide consumers with positive experiences. In addition, comparing with VR-based try-on, AR-based try-on technology enables users to try a number of augmented products overlaying on the user's body. Moreover, 3D garment models precisely simulate garments. The garment model matching 3D avatars can present a more accurate representation of the garment and its fit. It also provides users a multi-angle view of the garments. Accordingly, we build a personalized virtual try-on system using Augmented Reality to increase the user's shopping experience.

5.4.1 The workflow of AR-based Virtual Try-on

The workflow of AR-based virtual try-on is shown in Figure 5.11 below. The user can detect the plane and add her own embodied avatar on the plane, then she can manipulate her virtual avatar by resizing the avatar in a real life-size or mini size. Besides, users can rotate the avatar and examining the avatar wearing garments from different points of view.

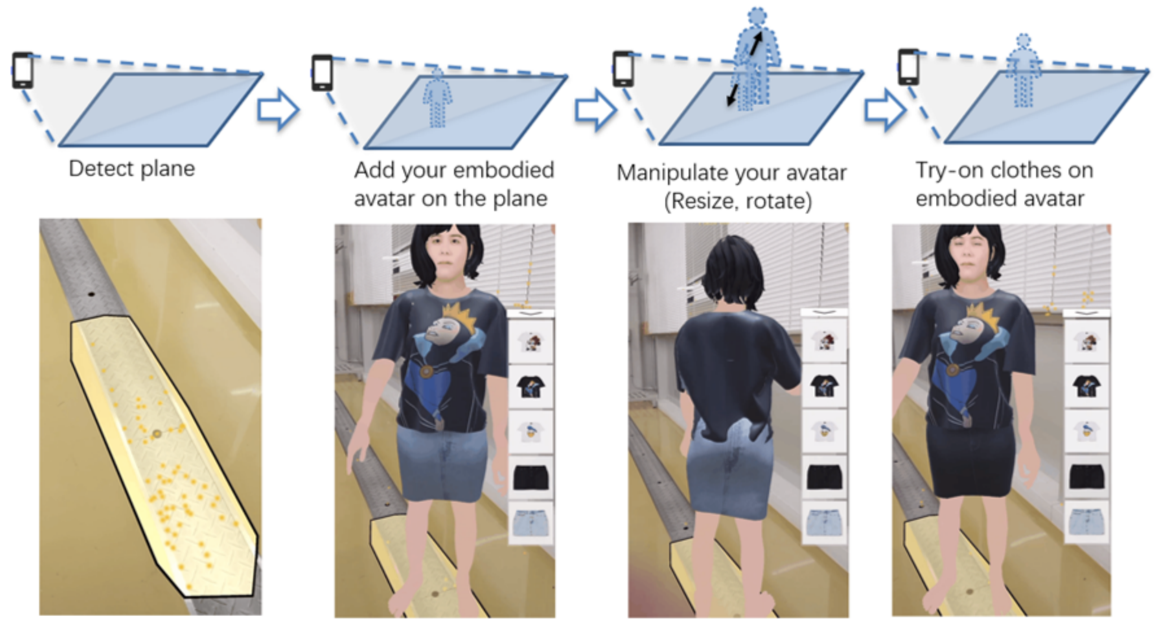


Fig. 5.11 The workflow of AR based virtual try-on

5.5 Sharing Virtual Try-on Experience

Initially, a Virtual try-on system has been developed and advanced to provide alternatives to the conversational physical fitting and to overcome the inherent challenge for online shopping, which is the inability to make physical interaction with the product and real people[31]. Merle et al and Moon found that a social connection system in VTO condition can gamify user's experience and satisfy the social and affective needs, thus enhancing hedonic experiences[9, 32].

In our daily life, the human is one of the most important factors of the virtual try-on system. We usually go shopping with our friends or family since they can provide some fashion ideas or comments to us. These kinds of social connections have not appeared in the previous virtual try-on system. To simulate the physical fitting and enrich the interactivity of a virtual try-on system, we decide to add the "social factors" to our system.

As "sharing" is the most important social factor in our life, the first thing we want to realize is to allow users to share their virtual try-on experience with other people. We build a fully personalized VTO system that can allow users to socially share their dynamic virtual try-on experience with other people, enabling them to have quick feedback as well.

5.5.1 Sharing AR experience

We consider sharing the AR-based virtual try-on experience for multiple users. Users in the virtual environment can be divided into two kinds:

1. Co-located users: users are located at the same physical location where face-to-face communication among the users is possible and practiced.

- **Sharing the virtual try-on experience with co-located users**

  For now, AR remains mostly a solo activity, but soon people might be using the technology for a variety of group activities. Figure 5.12 demonstrates the shared AR-based virtual try-on experience for two or more mobile devices.

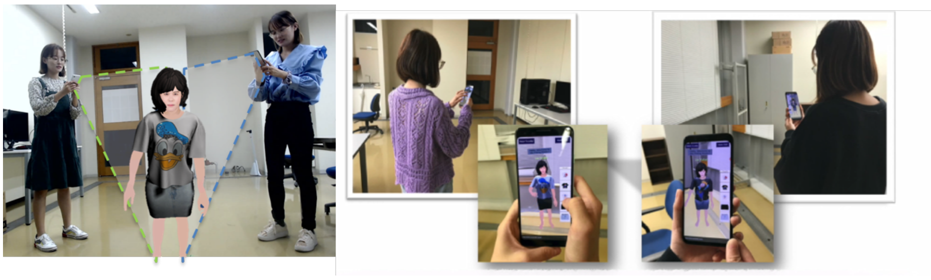


Fig. 5.12 Two users—Sharing Virtual Try-on Experience in local environment

When multiple users are in the same space, they can visualize the seemingly virtual object in the real environment related to their view position.

The using scenario can be shown in the following figure:

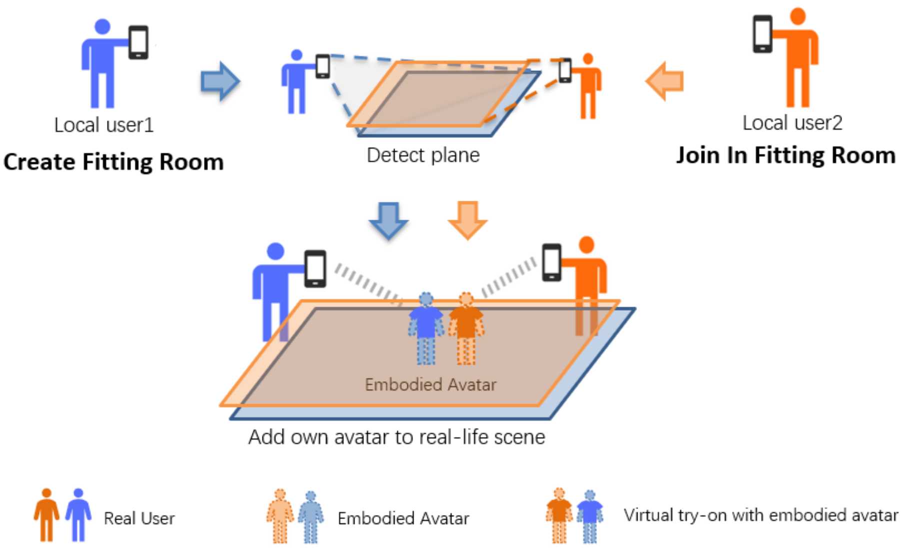


Fig. 5.13 The framework of Sharing Virtual Try-on with co-located users

1. Local user1 can first create a virtual fitting room, at the seem time the local user2 connecting the seem network with local user1 can search and join in the fitting room which is created by local user1.

2. Both local user1 and local user2 can detect the plane in the seem environment, and add their avatar on the plane.

3. co-located users can view their placed embodied avatar in the same real-world and see them on different devices in the same position and orientation relative to the environment. Both of them can try-on clothes on their own avatar or the other one's avatar and they can give some suggestions to each other to make a better decision.

2. Remote users: users are located at different physical locations.

- **Sharing virtual try-on experience with remote users**

  To increase the presence of users in the remote virtual environment, we use the embodied avatar to represent the remote user in a shared virtual try-on experience. Figure 5.12 demonstrates the shared AR-based virtual try-on experience for two or more mobile devices in the remote virtual environment.

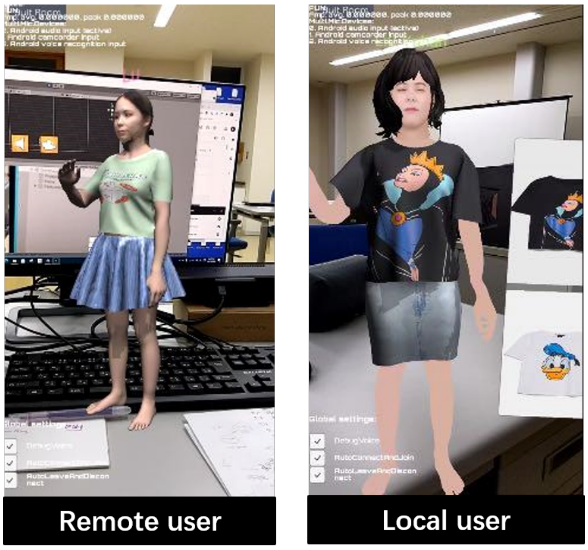


Fig. 5.14 Two users—Sharing Virtual Try-on Experience in local environment

When multiple users are in different spaces, they can view their virtual avatar in different environments and talk to each other in real-time.

The using scenario can be shown in the following figure:

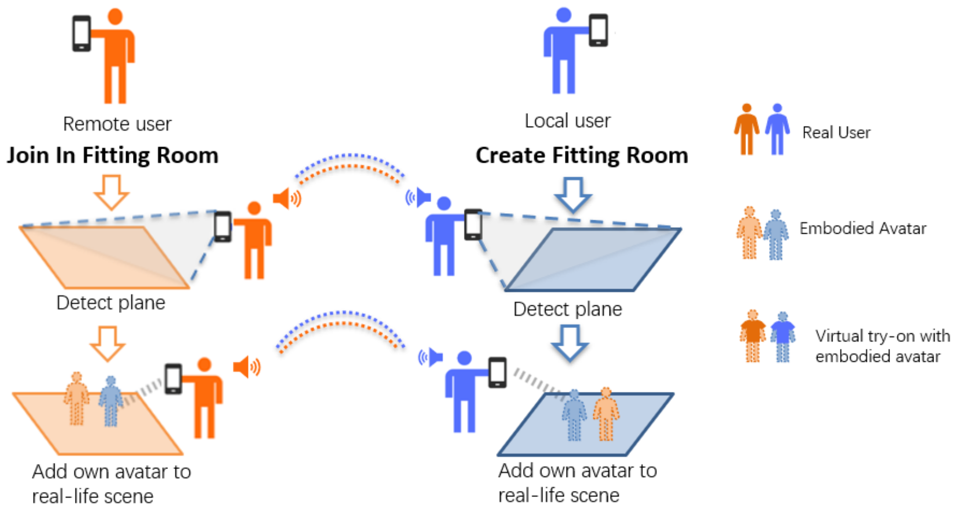


Fig. 5.15 The framework of Sharing Virtual Try-on with remote users

1. Local user can first create a virtual fitting room, at the same time the remote user can search and join in the fitting room which is created by the local user. Once the two users are in the seem virtual fitting room, they can talk to each other in real-time through the microphone.

2. Both local user and the remote user can detect the plane in the seem environment, and add their avatar on the plane.

3. The local and remote users can view their placed embodied avatar in different spaces and see them on different devices. Both of them can try-on clothes on their own avatar or the other one's avatar and they can give some suggestions to each other to make a better decision.

Chapter 6

System Implementation

6.1 Hardware Setup

6.1.1 Mobile Devices

Our virtual Try-on System offers users to simulate fitting experience together. This system is developed on the mobile platform which can allow multiple users to communicate and discuss conveniently, thereby simulating a more realistic physical fitting. Therefore, we need two mobile devices for multiple users using our system. We choose Google Pixel3[33] and Google Pixel4[33] and build our system on an Android platform.

Fig. 6.1 Mobile devices

6.1.2 MoCap Devices

To capture motion and skeleton information for each user, we use a Microsoft Kinect Xbox one sensor[34] as a depth sensor to record the RGBD information(include the color information and the depth information) and track the users' body movement. The depth sensor is connected to a computer with the Windows 10 operating system using a USB 3.0 controller and a Kinect adapter for windows.

Fig. 6.2 Kinect Xbox one Sensor

To increase the accuracy of recording movements for users. The environment should be open enough to capture movement, without interference from inanimate objects (desks, furniture, etc.). Therefore we prepare a Tripod for Kinect to adjusting the capture area of the Kinect sensor can accurately track users' movement[35].

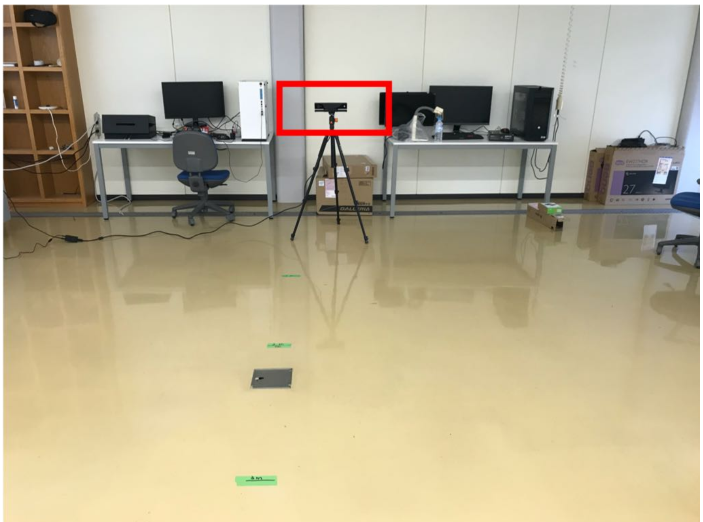


Fig. 6.3 Kinect tripod

6.1.3 Development Devices

In order to assess the data and build the system using SDK and software, we use a PC with Windows 10 operating system.

6.2 Software Environment

6.2.1 Development Tools

We develop our software using Unity game engine version 2019.4.3f1[36]. We generate some clothes 3D model using blender[37] and 3ds Max[38]. To smooth out the animation of users movement, we use 3d animation software Maya[39].

6.2.2 Technical Support

To build our system, we get some technical supports from:

1. 3D Avatar SDK[40], it supports a deep learning algorithm for generating a fixed topology head of 3D avatar from a single photo of the user;
2. 3D Look[41], is a 3D body model generation software which can generate a full 3D body shape of the user from two front and side body photos;
3. Cinema Mocap[42], is a marker-less motion capture solution for Unity to create customized animations for users.
4. Cinema Face cap[43], is an easy to use and affordable Facial Capture solution for Unity using the Microsoft Kinect sensor.
5. AR Foundation[44], AR Core[45], Vuforia SDK[46]: these SDK support for Augmented Reality development;
6. AR Cloud Anchor API[47]: it supports creating multi-person or collaborative AR experiences that Android and iOS users can share;

7. Photon Engine[48]: it supports multiple users application developments in Unity3D.

6.3 Personalize Embodied Avatar

We proposed that virtual body models should include users' own personalized motion and facial expressions, which are captured individually by each user. In this section, we discuss in detail the process of personalizing an embodied avatar for the user.

6.3.1 Personalized virtual avatar

First, we will personalize the appearance of the avatar for users. The process of personalizing a virtual avatar can be divided into two parts: the face model generation and the body model generating part.

- **Face Model Generation**: we personalize the appearance of the user's face based on the 3D Avatar SDK. the input is the 2D image of our face with no glasses or hair on the forehead. Figure 6.4 shows the procedure of mapping the texture to the user's 3D face.

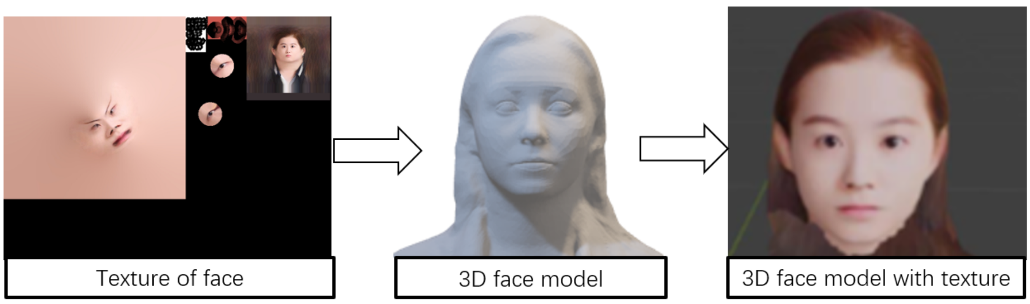


Fig. 6.4 Mapping texture to Face model

1. **Generate 3D face model through 3D avatar**: we upload the image of user's front face to the web sever of 3D avatar, then we can get the 3D face model with its texture, the format of 3D face model is .obj file, the format of texture is .png.
2. **Mapping texture of face to the generated 3D face model**: We can mapping the texture of face to its corresponding 3D face model and rending the 3D face

model with its texture in a blender. As a result, we can generate a realistic 3D face model based on a front face image of the user.

- **Body Model Generation**:

  1. **Gather basic information**: We generate a 3D body model based on the user's basic information, the height, and the weight of the user.

  2. **Capture the body shape of the user**: the front and side image of the user's full body shape are needed. The generated 3D model is outputted as a .obj file.

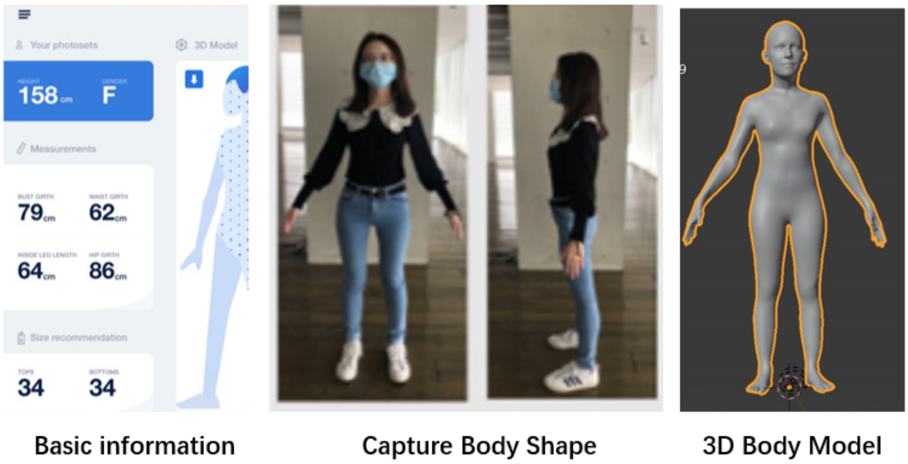


Fig. 6.5 Human model generation

6.3.2 Personalize Facial Expression of Avatar

We personalized the facial animation of the virtual avatar with the user's facial expression, which consists of three sections: motion capture, personalized facial expression

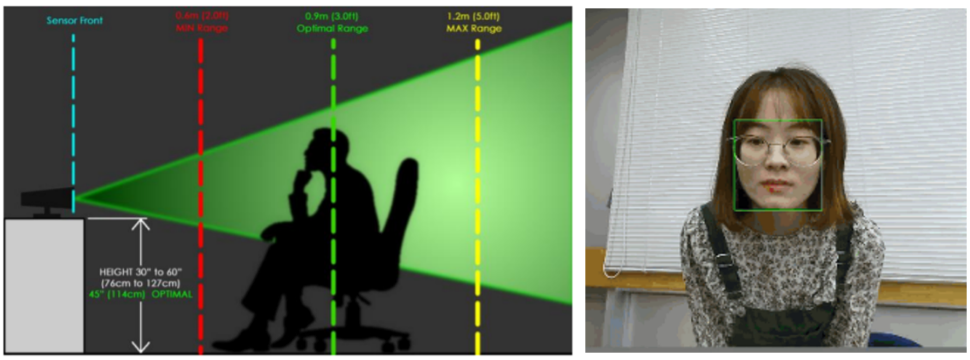
1. **Capture Facial Motion**: using Kinect depth sensor to track user's facial expression.

2. **Personalized Facial Expression**: attach user's facial expression to virtual avatar' face.

• Capture Facial Motion

The detailed process of capturing facial motion is shown below:

1. **K**inect setting: we first set up the Kinect depth sensor with a Kinect Adapter for Windows 10 PC. Download and install the Kinect for Windows SDK 2.0. Run the Kinect Studio v2.0 and manually click the Connect option in this tool to enable the use of the Kinect, so that it can display color and depth streams from the Kinect device.

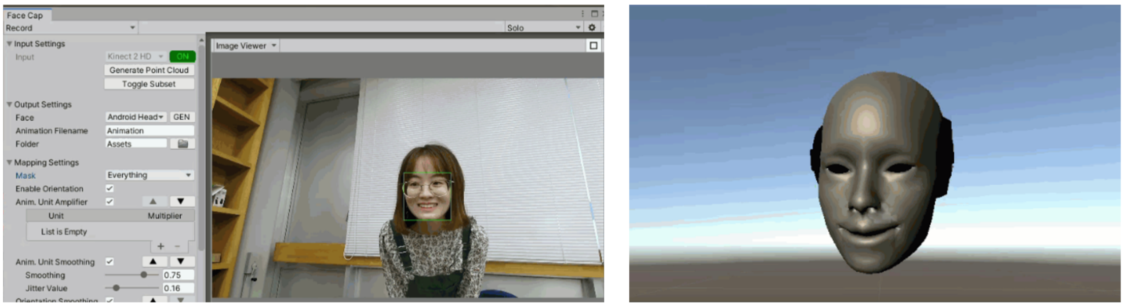


Capture optimal area   Recognized face

Fig. 6.6 Kinect setting

2. **Recording the facial expression of the user**: When using Cinema Face Cap, we should check the surroundings to make sure that we have enough space to operate. For the best results, the distance will be approximately 3 feet (0.9m) away from the Kinect sensor. The Kinect should be placed level, at approximately 45 inches (127cm)from the floor.

   To capture the user's facial expression, we use the Cinema Face Cap, which is a unity plugin. Hence, we should download the Face Cap into unity, and setting up the Kinect before recording the facial expression of the user. The recorded mocap data of the user can be converted into animation as a .anim file in the Unity project(Figure 6.7).



Recording facial motion using Kinect   Facial animation

Fig. 6.7 Recording the facial expression

- **Personalized Facial Expression**

The detailed process of Personalizing Facial Expression is shown below:

1. **Prepare the face model**: To control the 3D face model do some animations such as blinking, smiling, speaking, a complete 3D face model is required, not only the exterior of the training, but also the complete internal structure, such as eyeballs, teeth, and tongue.

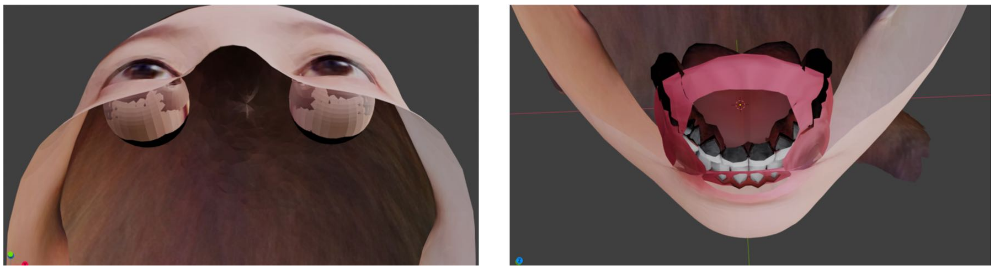


Fig. 6.8 Completed 3D Face model

2. **Blend shape mapping**: To make sure the captured facial animation can be attached to the prepared 3D face model, and control the corresponding part of the face moving, the 3D face model should include a blend shape. A blend shape is a deformed version of a shape. When applied to a human face, the head is first modeled with a neutral expression and a "target deformation" is then created for each other expression. When the face is being animated, the animator can then smoothly morph (or "blend") between the base shape and one or several morph targets. In a blend shape facial animation, a

"deformed" version of a mesh is stored as a series of vertex positions. In each keyframe of an animation, the vertices are then interpolated between these stored positions.

The information of the vertex positions in each frame is captured by Kinect and store as a .anim file. Figure 6.9 shows the face model with blend shape, Cinema Face Cap uses blend shapes to register the facial movements within the Kinect 2.0. The program is set to recognize 20 different blend shapes that should be attached to the characters FBX file.

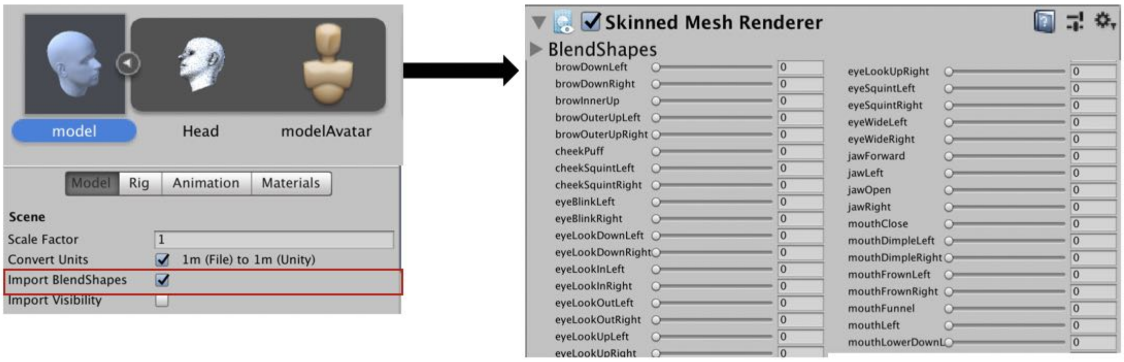


Fig. 6.9 Face model with blend shape

3. **Attach to prepared face model**: we create an animation controller to control the animation clip of facial expression, and add this controller to the 3D face model in the scene so that the face model can auto-play the facial animation with the system running.

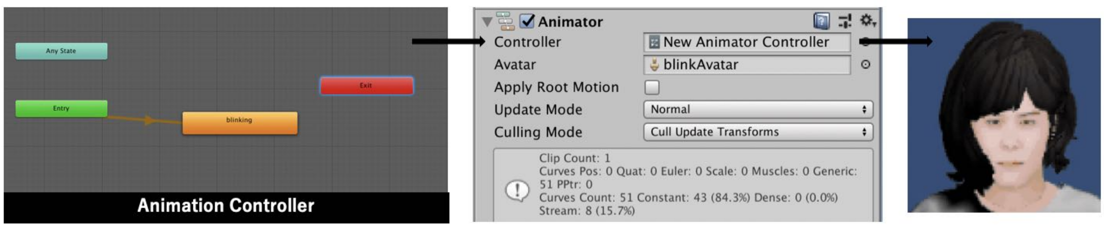


Fig. 6.10 Attach to prepared face model

6.3.3 Personalize Motion of Avatar

To gather users' individual movements, we use the Kinect V2 depth sensor to record postures and user movements and create their own animation library for our system. The recorded animations are then smoothed out using Maya and are then attached to the user's virtual avatar. To convert the captured mo-cap data into animation, we used a Unity plugin, Cinema-Mocap, which is a marker-less motion capture solution for Unity to create customized animations for users. As the movement captured by the Kinect V2 depth sensor is quite jittery, we edited and smoothed the animation frame-by-frame in Maya, which is a 3D computer animation, modeling, simulation, and rendering software. The animations are then imported into Unity and the animation is attached to the virtual avatars.

Our framework for motion capture using Kinect is shown in Figure 6.11. The movement of the users in the real world are converted into animation of the avatar in the virtual world using these three steps:

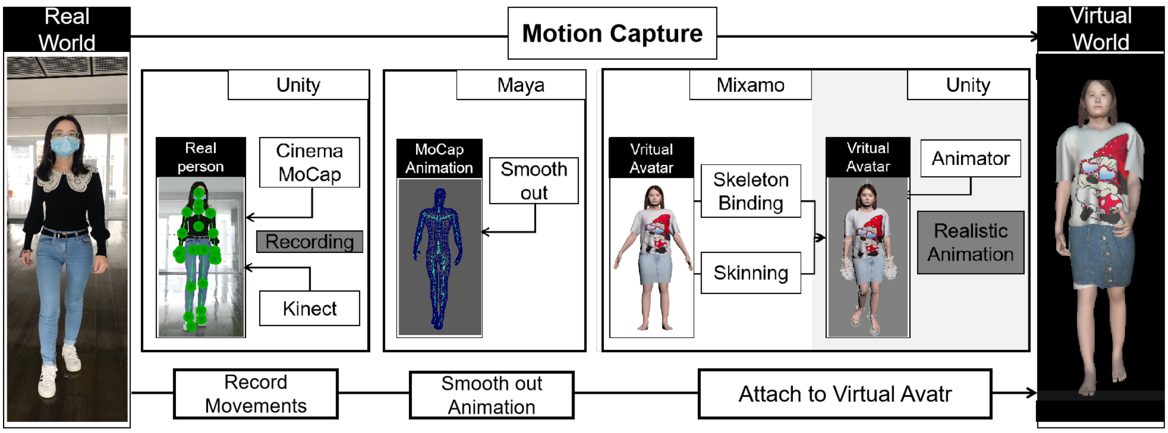


Fig. 6.11 Motion capture

1. **Motion capture**: We recorded users' movement using a Kinect V2 depth sensor and Cinema Mocap in Unity. Kinect V2 sensor was used as a skeleton camera to track users' body motion; Cinema Mocap in Unity was used to convert the motion capture data to avatar animation.

2. **Smooth out animation**: The animation captured by the Kinect V2 sensor contains trembling movements, which we smoothed out in Maya.

3. **Attach animation to virtual avatar**: Before attaching the animation to the avatar, we needed to rig the skeleton and the skin to the virtual avatar using Mixamo. Then, we used an animation controller in Unity to control the virtual avatar to perform humanoid and realistic animation.

   Following these three steps, users can view the virtual avatar with their personalized motion inside the VR or AR environment.

- **Motion Capture**: using Kinect depth sensor to track user's movement.

1. **Kinect setting**: The Kinect V2 depth sensor can track up to six bodies at a time within the visible range. The tracking accuracy is stable from 1 to 4 m in front of the depth sensor. We tracked users' movements in this range to reduce jitterily and increase stability. Depending on the height of the user, the optimal captured area of Kinect can be calculated and it is shown in Figure 6.12.

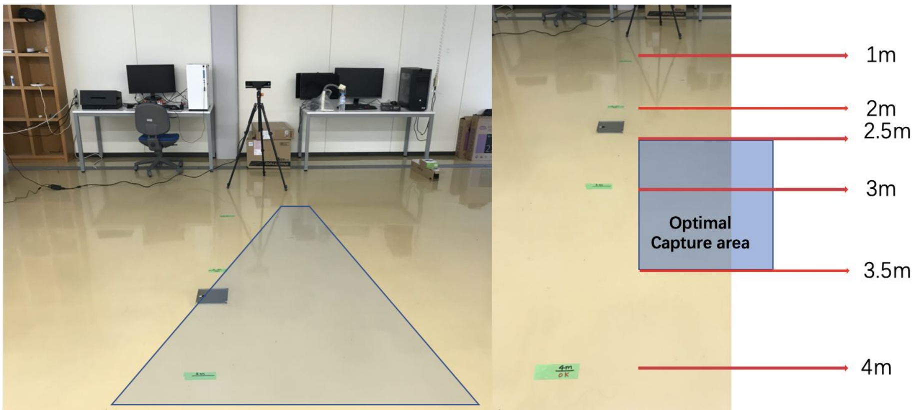
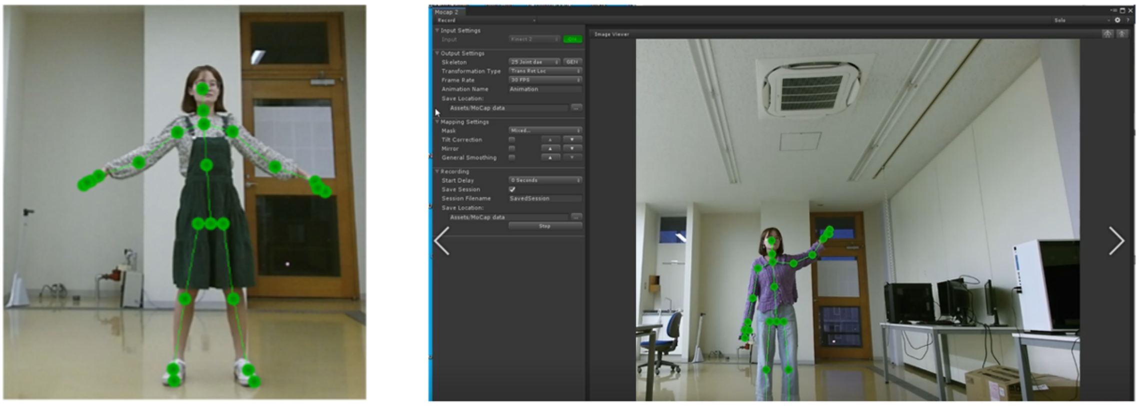


Fig. 6.12 Kinect capture optimal area

2. **Recording motion**: The Kinect V2 depth sensor provides 25 joints tracked at 30 frames per second; we accessed the joints using Kinect SDK. Figure 6.13 shows the various joints detected while skeleton tracking using Kinect V2 depth sensor.

   The motion capture data tracked by Kinect V2 depth sensor can be converted to animation and saved as a .dae file using Cinema Mocap.



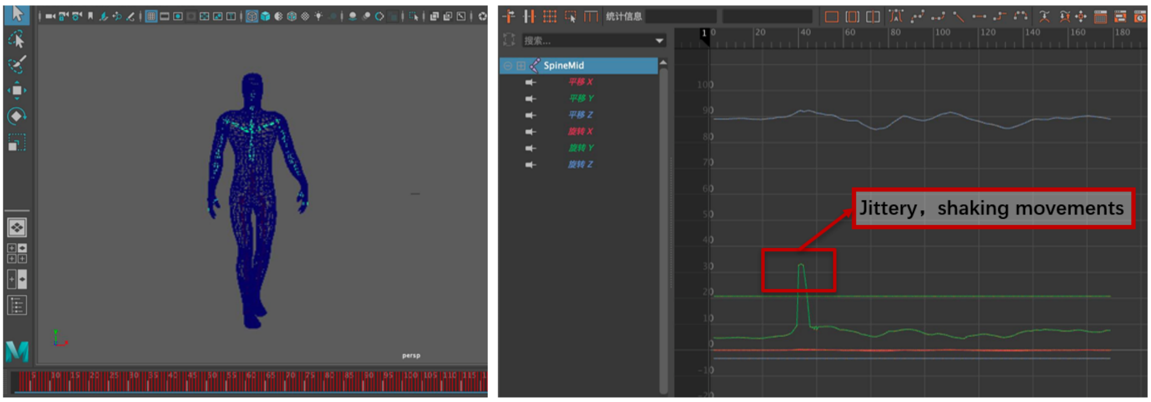
25 Joints detected by skeleton tracking on Kinect V2

Recording motion using Kinect

Fig. 6.13 Recording motion of the user using Kinect

• Smooth out animation

Due to the accuracy of motion capture, the motion captured by Kinect has some jittery or shaking movement, which may result in an unnatural animation. Therefore, a smooth out of animation should be done in Maya. we can import the captured motion data into Maya, which includes the position information of each joint in each frame of the user. The animated editing curve is used to check and fix the jittery movements. The jittery or shaking movements will be shown as a sudden peak in a movement curve.



Motion captured animation

Animated editing curve

Fig. 6.14 Smooth out animation in Maya

• **Attach animation to virtual avatar**: attach users motion to virtual avatar

1. **Skeleton binding and skinning**: To make sure the motion captured data can be controlled by a virtual avatar, we should first bind the skeleton and skin the virtual avatar using Mixamo. We rig the 25 joints of the virtual avatar since the number of joints that can be captured by Kinect is 25.

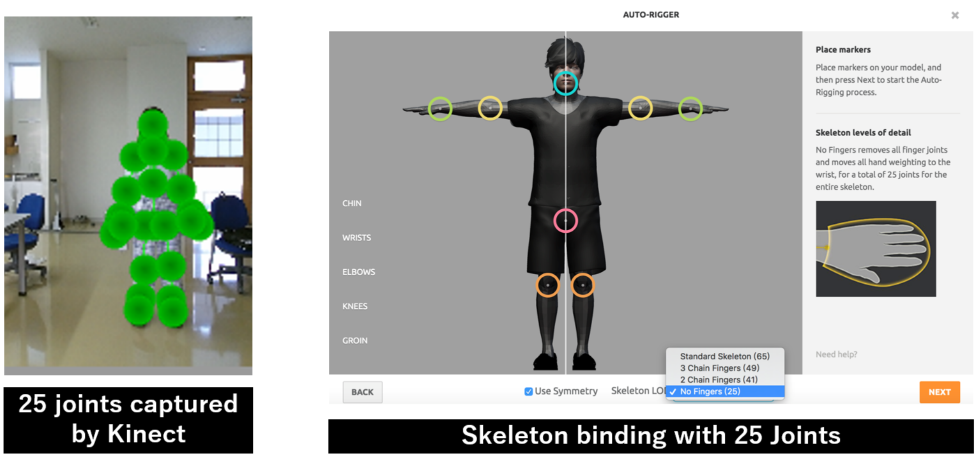


Fig. 6.15 Skeleton binding and skinning

2. **Animation controller**: First, we import the generated virtual avatar into unity and set the Animation type for Mocap and Virtual Avatar to "Humanoid”, then Create an Animator controller to control the Mocap animation play. Finally, the avatar can do the humanoid motion as they do in daily life.

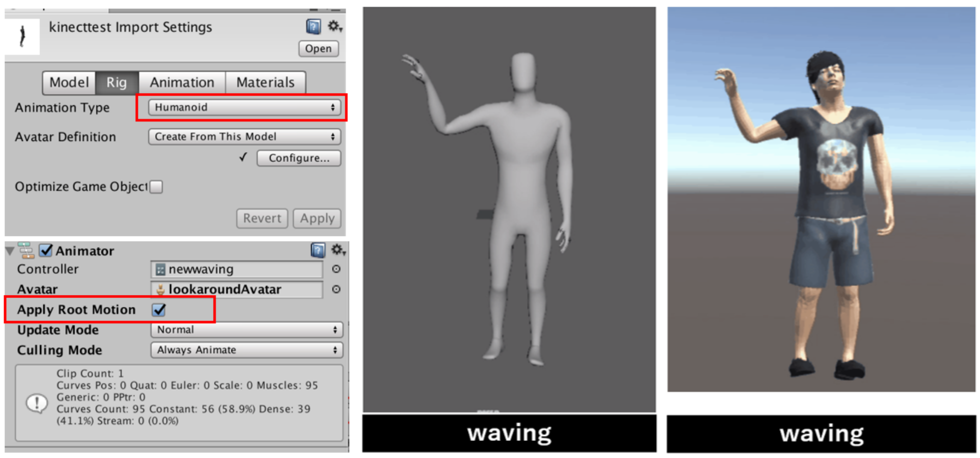


Fig. 6.16 Attach animation to virtual avatar

6.4 AR-based Virtual Try-on

To implement the AR-based virtual try-on system, we use the AR Foundation, ARcoreand Vuforia SDK.

The AR-based virtual try-on system is consists of three parts.

1. **Model visualization**: The virtual avatar will be visualized after the plane is recognized. We integrated the virtual avatar and UI components into a prefab to control the visualization of the virtual avatar and share the combined virtual object to all users through the network.

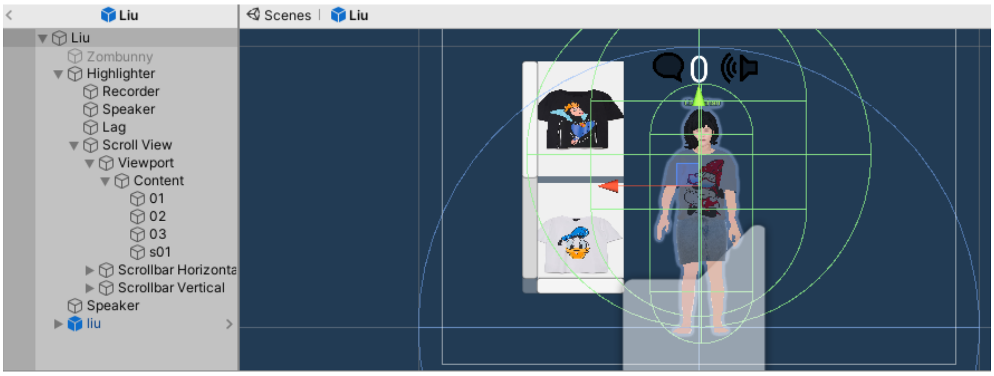


Fig. 6.17 Model prefab

2. **Model manipulation**: The user's virtual avatar can provide a 360-degree view for users. For users, they can manipulate the virtual avatar from different points of view and scale the avatar to check the detail of the garment model. Figure 6.18 shows how we realize the rotation and scale.

3. **Virtual try-on**: The users can change the clothes when they select the clothes they want. We prepare several garments for the user's selection.

```
if (Input.GetTouch(0).phase == TouchPhase.Moved)
{
    x = Input.GetAxis("Mouse X") * xSpeed;
    transform.Rotate(Vector3.up * -x * Time.deltaTime, Space.Self);
}
if (Input.touchCount > 1)
{
    if (Input.GetTouch(0).phase == TouchPhase.Moved && Input.GetTouch(1).phase == TouchPhase.Moved)
    {
        Vector2 tempPosition1 = Input.GetTouch(0).position;
        Vector2 tempPosition2 = Input.GetTouch(1).position;
        if (isEnlarge(oldPosition1, oldPosition2, tempPosition1, tempPosition2))
        {
            float oldScale = transform.localScale.x;
            float newScale = oldScale * 1.025f;
            transform.localScale = new Vector3(newScale, newScale, newScale);
        }
        else
        {
            float oldScale = transform.localScale.x;
            float newScale = oldScale / 1.025f;
            transform.localScale = new Vector3(newScale, newScale, newScale);
        }
        oldPosition1 = tempPosition1;
        oldPosition2 = tempPosition2;
    }
}
```

Fig. 6.18 Rotate and scale the avatar

6.5 Sharing Virtual Try-on

As "sharing" is the most important social factor in our life, the first thing we want to realize is to allow users to share their virtual try-on experience with other people.

6.5.1 Sharing AR experience

To realize sharing the virtual try-on experience with other people in the Augmented Reality world, we implement the AR Core, Vuforia, and AR cloud. To achieve communication among users in remote space, we use the Photon SDK.

6.5.2 Sharing Virtual Try-on with Co-located users

To share the virtual try-on experience with co-located users, we use AR Cloud Anchors API supports by google.

Cloud Anchors are anchors that are hosted in the cloud and can be resolved by multiple users to establish a common frame of reference across users and their devices[49].

The implementation of AR Cloud Anchor can be divided into these steps.

1. **Install package and plugin in unity**: I implement the AR Cloud anchor on Unity3D 2019.4.3f, and I install several packages in unity to make sure the AR function and multiple interactions could be available. To ensure that the development environment could be stable, I install version 3.1.0 of the AR Foundation package and ARCore XR Plugin package.

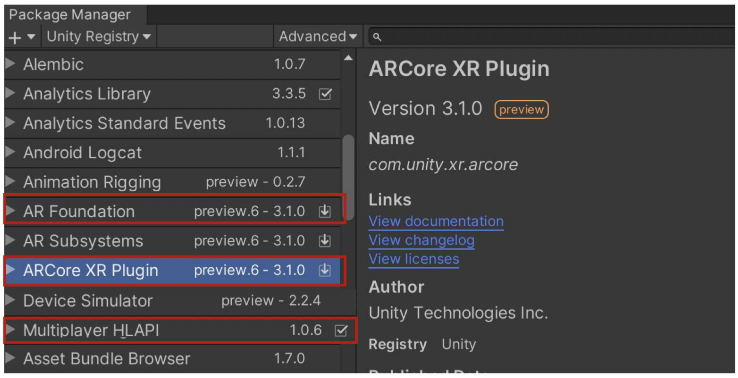


Fig. 6.19 Installed package and plugin in unity

2. **Set up the multiplayer service in unity**: firstly, I install the Multiplayer HLAPI package as the plugin in unity. then we should allow the multiplayer service, sign in the account of unity, and setup Unity Multiplayer in the dashboard. Then specify the maximum number of users per room as number 10.

3. **Enable APIs and Services**: in order to use the ARCore Cloud Anchors, I sign in a Google API account and navigate to the Credentials panel to create a Google Cloud API Key. Then in the unity project, I switch to Edit > Project Settings > XR > ARCore Extensions and add it to Cloud Anchor API Keys.

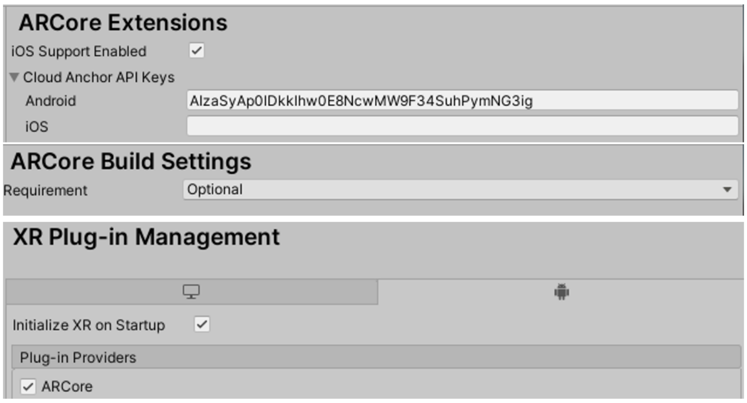


Fig. 6.20 Enable APIs and Services in Unity

In order to achieve these shared experiences, ARCore connects to the ARCore cloud anchor service to host and resolve anchors. This requires an effective network connection. Hosting and resolution involve the following steps:

1. The user creates a local anchor in his own environment. Once the user hits the screen, the virtual object is instantiated in the scene.

2. During the hosting period, ARCore uploads the anchor point data to the ARCore cloud anchor point service, which will return the unique ID of the anchor point, the application distributes the unique ID to other users. Then the position information of the anchor can be shared with users.

3. We instantiate a virtual embodied avatar as an anchor of user's so that users can assess the same virtual contents on different devices in the same environment and do some interaction and manipulation with virtual objects.

```
private void _InstantiateAnchor(ARAnchor anchor)
{
    GameObject.Find("LocalPlayer1").GetComponent<LocalPlayerController>()
        .SpawnAnchor(anchor);
}

public void SpawnAnchor(ARAnchor anchor)
{
    var anchorObject = Instantiate(AnchorPrefab, Vector3.zero, Quaternion.identity);
    anchorObject.GetComponent<AnchorController>().HostAnchor(anchor);
    NetworkServer.Spawn(anchorObject);
}
```

Fig. 6.21 Enable APIs and Services in Unity

6.5.3 Sharing Virtual Try-on with Remote users

To share the virtual try-on experience with remote users, we use the Photon SDK to transform the voice data and virtual digital data between users. To realize the sharing experience among multiple users in unity, we first install SDKs. The Photon Realtime SDK is the lean and core API to access all Photon Cloud Services. It is the base for the higher level multiplayer SDKs[48]. The communication SDKs, Photon VOICE, and CHAT are used for real-time talking between users. To Enable SDKs and Services, I sign in to a PUN account and navigate to the dashboard add the photon cloud applications and get the Cloud APP ID.

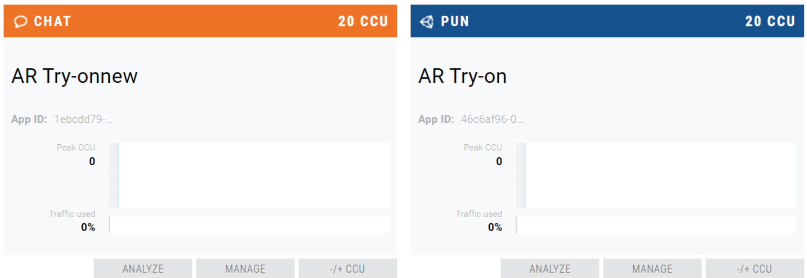


Fig. 6.22 Photon Cloud APP ID setting up in dashboard

The Unity Client encrypts the data through the prepared Protocols through the PUN SDK and sends it to Photon Cloud, which is processed by the upper server, and the data(animation of users, virtual object) is synchronized to other Clients connected to the same room. we adopt the Photon CHAT SDK to keep your users communicating while they are online (Figure 6.23).

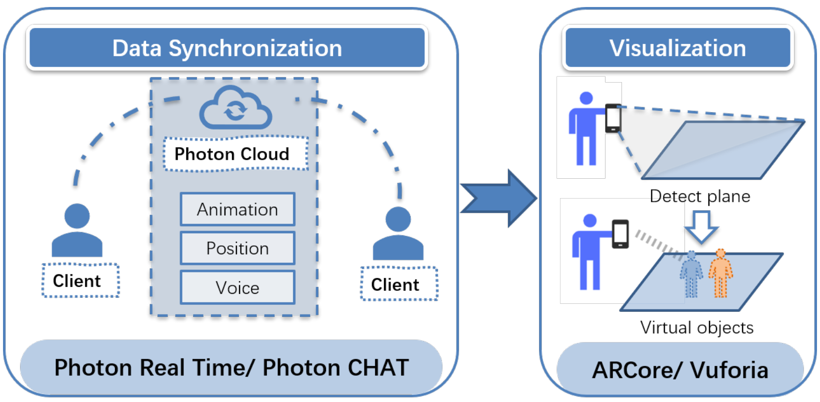


Fig. 6.23 Workflow of Sharing AR experience with remote users

Chapter 7

User Study

In this section, we introduce our preliminary user study and result in analysis. We asked our participants to simulate online shopping with our system in order to verify whether our system can provide better experiences and better efficiency when compared with the independent AR-based try-on system. Our discussion is based on the received results and received feedback from a questionnaire.

7.1 Participants

We recruited 12 participants (6 females, 6 males). Participants aged 20-25 years are usually targeted by AR/VR applications, as they are more likely to try new technologies and they are proactive in online shopping for fashion products. Furthermore, we gathered their relationship with their partner by the inclusion of the community in self-scale (IOS) [50]. As Figure 7.1 shows, IOS is a general evaluation of how they perceived their relationship with others. The first one shows they are not familiar with each other, the last one shows they are very close with each other.We asked the participants to rate their relationship with the other participant in a pair by using IOS.

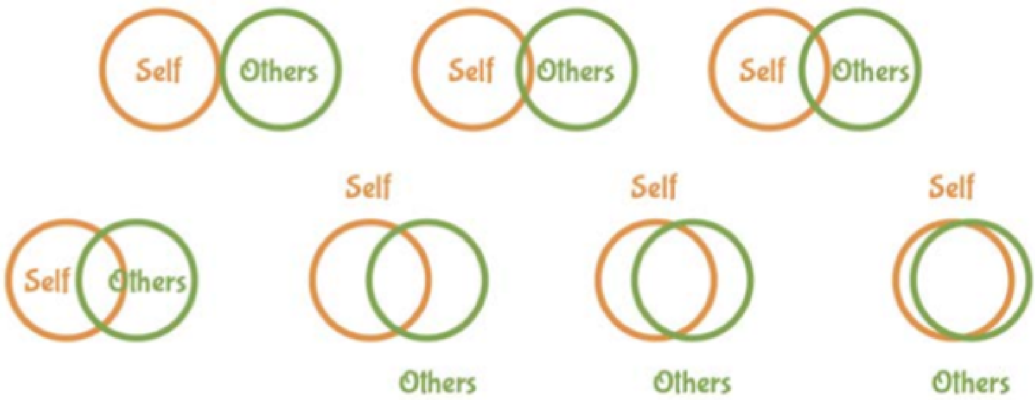


Fig. 7.1 The inclusion of community in self-scale

7.2 Experimental Design

Our study used a within-subject design in which two participants used the VTO systems with two different modes of independent and co-located AR-based VTO in random order. The two conditions were (Figure 7.2): (1) Independent AR-based VTO: Participants individually put their virtual avatar in each real environment and view their own personalized virtual body with garments models and posing or walking in the real world. (2) Co-located AR-based VTO: Participants can share their virtual try-on experience with their partners at the same time and in the same place. They can communicate verbally and visually and give comments on each other's fitting effects.

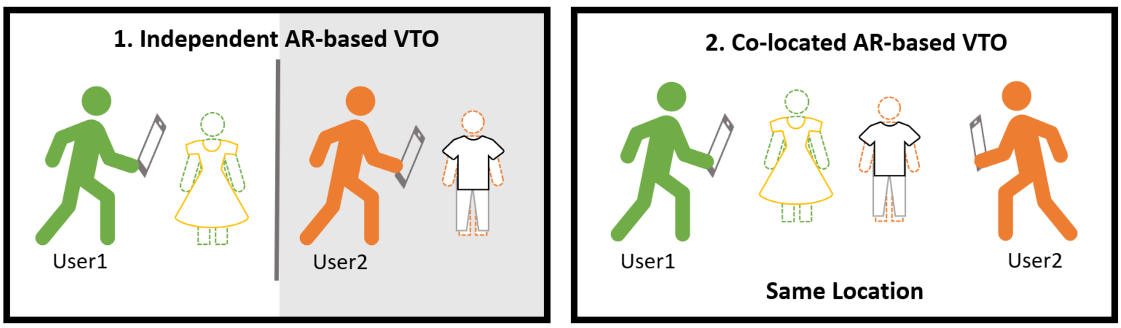


Fig. 7.2 The experiment conditions

We separated participants into 6 pairs, where people of the same sex are in the same group. We asked each pair of participants to virtually try the clothes on and simulate the shopping experience with independent AR-based try-on condition and co-located AR-based try-on conditions. After each section, participants were asked to complete a 7-point Likert scale questionnaire to rate their shopping experience in the terms of body similarity, comfort, enjoyment, happiness, usefulness, fit problem, purchase intention, Attitude toward shopping technology. The questionnaire and measurement items are shown in Table 1. At the end of the experiment, we interviewed the participants and gathered some open-ended feedback.

Table 7.1 Questionnaire and measurement items. Note: The questions with bold fonts is only considered in the case of co-located AR-based try-on condition.

Items	Questions
Body similarity	I feel that the virtual body I saw was my own body.
	I feel that the other virtual body I saw was my partner.
Enjoyment	Using this virtual try-on system was enjoyable for me.
	I feel happy when I am shopping with my partner.
Effectiveness	Using this virtual try-on system would enhance my effectiveness in shopping.
	Communicate with my partner would give me a helpful comment.
Fit problem	I think the clothes I choose are suitable for me.
Purchase intention	It is likely that I would purchase this product.
Attitude toward technology	I want to use this system when I buy some clothes online in the future.

7.3 Result

7.3.1 Quantitative Analysis

Paired T-test was performed using SPSS [51] to assess whether there were statistically significant differences between the means of the two conditions. Figure 5 shows the differences between the two conditions in various items. Paired T-test result shows that the co-located AR-based try-on system performs better than independent AR-based try-on system in 'Enjoyment' ($p < 0.05$), 'Usefulness' ($p < 0.05$), 'Attitude toward shopping technology ' (p

< 0.01), while no significant difference is found in 'Body similarity ' (p =0.59), 'Confidence in fit problem' (p = 0.53) and 'Purchase intention(p=0.34)'. We also asked participants' preferences for each condition at the end of the study. As a result, 11 participants preferred the co-located AR-based try-on condition, only one participant liked the AR-based independent try-on because he was worried that sharing his body with others would reveal privacy.

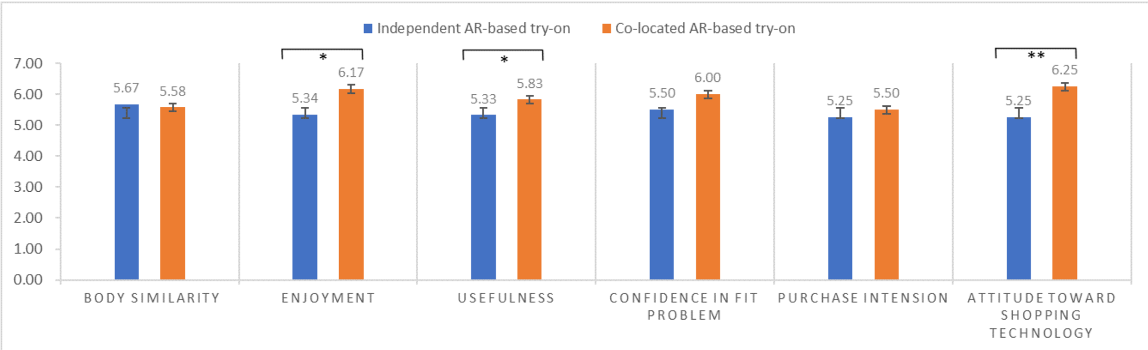


Fig. 7.3 Perceived levels of body similarity, enjoyment, usefulness, confidence in fit problem, purchase intention, attitude toward shopping technology. Note: *p < 0.05, **p < 0.01.

7.3.2 Qualitative Analysis

We report findings from our observations and semi-structured interview in four themes.

Theme 1 — Helpful comments Effectiveness

The shared virtual try-on experience improves the shortcomings of the lack of real-time communication and feedback when shopping online and can provide users with a more useful shopping experience. Most participants mentioned that they often share links or pictures of clothes with their friends or family and want to hear their opinions when online shopping. However, just by sharing 2D pictures, it is very difficult to get accurate opinions from other peoples. Using the co-located AR-based try-on system, users can share their 3D dressed bodies with others. In this way, users can receive more helpful comments from other people.

"I can get some helpful comments from my partner When I shared my virtual try-on experience with her." (P10) *"When I shop online alone, the styles of clothes I can choose from are very single. When using this system, friends can give me some suggestions, allowing*

me to try some new styles." (P6) *"This system can share my try-on experience with my friend. Therefore, I can receive some more helpful advice than traditional online shopping way."*(P8)

Participants think that sharing their virtual try-on experience with their partners would enhance their effectiveness in shopping. For example, P4 mentioned that "friends can quickly help themselves filtered unsuitable clothes by observing their own fitting effects. Greatly save shopping time."

Theme 2 — Happiness and closeness with others Participants reported feeling happy and closer with their partners after using this system. Participants strongly agreed that they feel happy (M=6.58 SD= 0.64) when shopping with their partners. For instance, P1 mentioned that *"It allows me to experience the pleasure of shopping with friends."*, Furthermore, P12 noted that *"Seeing our avatars doing real-life motions in the real world, this kind of game-like try-on experience makes me very happy."*

Participants reported closeness with their partners also increased from an average IOS score of 4.66(SD=1.15) to 5.08(SD=1.24) after the experiment (P<0.05).

"It's fun to try on clothes in the same space with friend's avatars. We can talk to each other, see each other's avatars, and then interact with each other. I think our relationship has become closer." (P2) *"Using this system to do online shopping with friends can strengthen social connections and enhance the relationship with my friend."* (P9)

Theme 3 — Engagement Participants have strongly agreed that they had fun and feel engaged in the co-located AR-based try-on condition. We found that participants tend to spend more time and more engaged in shopping together with their partners in the co-located AR-based try-on condition. Compared with the independent virtual try-on, they paid more attention to help friends choose clothes and give their novel opinions.

"It's fun to try on clothes for my partner." (P11) *"I can get new ideas from other people's comments. Because both of us can intuitively see the effect of each other's virtual try-on. we can put on the clothes that each other chooses for ourselves, and then discuss according to the effect of the virtual try-on."* (P5)

Theme 4 — Body similarity Participants self-reported that co-located AR-based try-on can increase their awareness of their bodies. For instance, P1 mentioned that "Standing with my friends increases my familiarity with my virtual body. Therefore, I think my virtual body is very similar to me." In addition, we found that friends' evaluations of their virtual bodies often affect their perception of their virtual avatar. Several participants mentioned that when they heard positive feedback from friends ("This virtual avatar really looks like you"), they felt that the virtual body became more similar to themselves. On the other hand, when participants heard negative comments from friends, they reduced the ratings of their virtual avatar.

We summarize the main results and present explanatory analysis using our observation during the study as well as findings that come out from the interview. The results indicated that the Soical Fitme can greatly improve the shopping pleasure of users and provide a more engaging and effective shopping experience for users. Our system provides users an intuitive sharing VTO experience, users can communicate with each other and then make a more confidence decision. Users can enhance their relationship and strengthen their social connection by using our system. We summarize the results in the following Table 1.

Table 7.2 Conclusion of Result

Categories	**Conclusions**
Effectiveness	**Helpful comments:** comments from others can help users to make a better choice. **Diversified styles:** users can change their styles according some comments from others. **Intuitive sharing experience:** personalized avatars in AR provide a more intuitive way to share their outfits with others when online shopping, which can offer users a better judge of fit. **Filter mismatched selection:** users can eliminate the unsuitable selections quickly. **Detailed garment visualization:** users can view garments with Multi-angles and more details.
Closeness	**Enhance relationship:** using the Social Fitme makes users feel closer with each other.
Enjoyment	**More engaged:** users are more enjoyable and engaged in sharing outfits with others, they tend to ask for other's recommendations and make a more confident choice. **Game-like shopping experience:** users feel happier when simulate try-on experience with others.

Chapter 8

Conclusion and Future Work

8.1 Conclusion

We presented Social Fitme, a platform and concept for co-located social try-on system that supports personalized interactions through smartphones. The system implements interactive technology combined with AR and cloud technologies and provides users with a novel shopping experience. We conduct a user study to explore the effectiveness of our system and interactions designed to support the sharing of VTO experience in AR. We found some possibilities and advantages of multi-user online social shopping:

- Try clothes on your friends directly. Rather than just imagine how the clothes looks like on their friend's body, users can try clothes on the personalized avatar of their friend directly and view the effect on the dressed virtual body in the real-life scene quickly.
- Explore a completely new style. Our system allows users to experience the pleasure of physical shopping with friends, allowing them to choose clothes for each other, or even explore a completely new style that they would otherwise not try on by themselves.
- More confident decision. The sharing VTO experience in AR can provide users with a more effective shopping experience. Sharing the intuitive dressed body allows users to

get more accurate comments from others thereby helping them make a more confident purchase decision.

- Strengthen social connection. The rating of IOS showed that the shared VTO system can strengthen social relationship between friends and make users feel closer with each other.

8.2 Future Work

In the future, we would improve our works from these two aspects:

(1) Improve sense of realistic personalization on virtual try-on: Our personalization research result in VTO shows that the level of personalization can be improved to a certain extent, such that the realism and interactivity of VTO may be increased (e.g. Face expression of virtual avatar). Several participants mentioned that they the facial expressions to make the virtual avatar more natural/humanlike and share the emotional attitude towards virtual clothes with others. While the motion captured by Kinect is not smooth as real actions, which may influence the user's experience when shopping. Thus, future work may explore designs of the personalized avatars to provide a natural and interactive sharing VTO experience for users.

(2) Enrich more social interactions in Virtual Try-on: Our system allows users to share their virtual avatar with others from a social interaction perspective. We present a new way for multiple users to do a virtual try-on experience in the local space. We also applied the shared AR-based try-on system to remote users, allowing multiple users to cross distance barriers and share fittings through natural communication. While some participants argued that the interaction between users is limited. Furthermore, we would expand the interactions between users and avatars. We would allow users to do some natural interactions with the environment and the other users, which might enhance their shopping experience.

References

[1] ChiPeer. The evolution of online shopping-why e-commerce is the new reality, Oct 2019.

[2] Kasia Gola. From the beginnings of the fashion ecommerce, through social shopping, to a vision of the clothes and accessories shops of the future, Mar 2015.

[3] The development of online shopping marketing essay.

[4] Valentina Zezelj. Virtual try-on: what it is and why your brand needs one, Nov 2020.

[5] Hanna Lee and Karen Leonas. Consumer experiences, the key to survive in an omni-channel environment: use of virtual technology. *Journal of Textile and Apparel, Technology and Management*, 10(3), 2018.

[6] Marsha L Richins. Social comparison and the idealized images of advertising. *Journal of consumer research*, 18(1):71–83, 1991.

[7] Ann Marie Fiore and Hyun-Jeong Jin. Influence of image interactivity on approach responses towards an online retailer. *Internet Research*, 2003.

[8] Ann Marie Fiore, Hyun-Jeong Jin, and Jihyun Kim. For fun and profit: Hedonic value from image interactivity and responses toward an online store. *Psychology & Marketing*, 22(8):669–694, 2005.

[9] Aurélie Merle, Sylvain Senecal, and Anik St-Onge. Whether and how virtual try-on influences consumer responses to an apparel web site. *International Journal of Electronic Commerce*, 16(3):41–64, 2012.

[10] Miaolong Yuan, Ishtiaq Rasool Khan, Farzam Farbiz, Susu Yao, Arthur Niswar, and Min-Hui Foo. A mixed reality virtual clothes try-on system. *IEEE Transactions on Multimedia*, 15(8):1958–1968, 2013.

[11] Nadia Magnenat-Thalmann, Bart Kevelham, Pascal Volino, Mustafa Kasap, and Etienne Lyard. 3d web-based virtual try on of physically simulated clothes. *Computer-Aided Design and Applications*, 8(2):163–174, 2011.

[12] Shuai Yang and Guiyang Xiong. Try it on! contingency effects of virtual fitting rooms. *Journal of Management Information Systems*, 36(3):789–822, 2019.

[13] Anne Thaler, Ivelina Piryankova, Jeanine K Stefanucci, Sergi Pujades, Stephan de La Rosa, Stephan Streuber, Javier Romero, Michael J Black, and Betty J Mohler. Visual perception and evaluation of photo-realistic self-avatars from 3d body scans in males and females. *Frontiers in ICT*, 5:18, 2018.

[14] Jiyeon Kim and Sandra Forsythe. Adoption of virtual try-on technology for online apparel shopping. *Journal of Interactive Marketing*, 22(2):45–59, 2008.

[15] Rong Li, Kun Zou, Xiang Xu, Yueqiao Li, and Zan Li. Research of interactive 3d virtual fitting room on web environment. In *2011 Fourth International Symposium on Computational Intelligence and Design*, volume 1, pages 32–35. IEEE, 2011.

[16] Yuwei Meng, PY Mok, and Xiaogang Jin. Interactive virtual try-on clothing design systems. *Computer-Aided Design*, 42(4):310–321, 2010.

[17] Warehouse. https://www.warehousefashion.com/womens/dresses.

[18] Shun Cai and Yunjie Xu. Designing not just for pleasure: effects of web site aesthetics on consumer shopping value. *International Journal of Electronic Commerce*, 15(4):159–188, 2011.

[19] Gerald Häubl and Valerie Trifts. Consumer decision making in online shopping environments: The effects of interactive decision aids. *Marketing science*, 19(1):4–21, 2000.

[20] Sylvain Senecal and Jacques Nantel. The influence of online product recommendations on consumers' online choices. *Journal of retailing*, 80(2):159–169, 2004.

[21] Kar Yan Tam and Shuk Ying Ho. Understanding the impact of web personalization on user information processing and decision outcomes. *MIS quarterly*, pages 865–890, 2006.

[22] Brianna Beck, Flavia Cardini, Elisabetta Làdavas, and Caterina Bertini. The enfacement illusion is not affected by negative facial expressions. *PloS one*, 10(8):e0136273, 2015.

[23] Mar Gonzalez-Franco, Anthony Steed, Steve Hoogendyk, and Eyal Ofek. Using facial animation to increase the enfacement illusion and avatar self-identification. *IEEE Transactions on Visualization and Computer Graphics*, 26(5):2023–2029, 2020.

[24] Richard Skarbez, Solene Neyret, Frederick P Brooks, Mel Slater, and Mary C Whitton. A psychophysical experiment regarding components of the plausibility illusion. *IEEE transactions on visualization and computer graphics*, 23(4):1369–1378, 2017.

[25] Syazwan Noordin, Noraidah Sahari Ashaari, and Tengku Siti Meriam Tengku Wook. Virtual fitting room: the needs for usability and profound emotional elements. In *2017 6th International Conference on Electrical Engineering and Informatics (ICEEI)*, pages 1–6. IEEE, 2017.

[26] Justine Cassell, Joseph Sullivan, Elizabeth Churchill, and Scott Prevost. *Embodied conversational agents*. MIT press, 2000.

[27] Catherine Pelachaud and Isabella Poggi. Subtleties of facial expressions in embodied agents. *The Journal of Visualization and Computer Animation*, 13(5):301–312, 2002.

[28] Yuzhao Liu, Yuhan Liu, Shihui Xu, Kelvin Cheng, Soh Masuko, and Jiro Tanaka. Comparing vr-and ar-based try-on systems using personalized avatars. *Electronics*, 9(11):1814, 2020.

[29] Umut Gültepe and Uğur Güdükbay. Real-time virtual fitting with body measurement and motion smoothing. *Computers & Graphics*, 43:31–43, 2014.

[30] Sasadara B Adikari, Naleen C Ganegoda, Ravinda GN Meegama, and Indika L Wanniarachchi. Applicability of a single depth sensor in real-time 3d clothes simulation: Augmented reality virtual dressing room using kinect sensor. *Advances in Human-Computer Interaction*, 2020, 2020.

[31] Marta Blázquez. Fashion shopping in multichannel retail: The role of technology in enhancing the customer experience. *International Journal of Electronic Commerce*, 18(4):97–116, 2014.

[32] Jang Ho Moon, Eunice Kim, Sejung Marina Choi, and Yongjun Sung. Keep the social in social media: The role of social interaction in avatar-based virtual shopping. *Journal of Interactive Advertising*, 13(1):14–26, 2013.

[33] Google pixel phones. https://store.google.com/magazine/compare_pixel.

[34] Kinect. https://en.wikipeda.org/wiki/Kinect.

[35] Kinectmocap. http://www.cinema-suite.com/Documentation/CinemaMoCap/Current/CinemaMoCapDocumentation.pdf.

[36] unity. https://unity.com/.

[37] Blender. https://www.blender.org/.

[38] 3dsmax. https://www.autodesk.co.jp/products/3ds-max/subscribe.

[39] Maya. https://www.autodesk.co.jp/products/maya/overview.

[40] 3davatar. https://avatarsdk.com/.

[41] 3dlook. https://3dlook.me/.

[42] cinemamocap. http://cinema-suite.com/cinema-mo-cap/.

[43] facemocap. https://transforminteractive.com/cinema-face-cap/.

[44] vuforia. https://docs.unity3d.com/Packages/com.unity.xr.arfoundation@4.1/manual/index.html.

[45] arcore. https://developers.google.com/ar.

[46] vuforia. https://developer.vuforia.com/.

[47] Cloud anchors overview for android nbsp;|nbsp; arcore nbsp;|nbsp; google developers.

[48] photonengine. https://www.photonengine.com/.

[49] Loredana Petrea. Ar technology for android-part 4nbsp;: Ar cloud anchors, Jun 2019.

[50] Debra Mashek, Lisa W Cannaday, and June P Tangney. Inclusion of community in self scale: A single-item pictorial measure of community connectedness. *Journal of Community Psychology*, 35(2):257–275, 2007.

[51] Spss. https://www.ibm.com/analytics/spss-statistics-software.